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THE CALIFORNIA FLATHEADED BORER, MELANOPHILA CALIFORNICA VAN DYKE AND THE PINE FLATHEADED BORER, MELANOPHILA GENTILIS LEC

A Review of Progress of Studies Conducted at the Hackamore Field Laboratory during the Seasons of 1936-1939.

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Forest Insect Laboratory
Berkeley, California
November 2, 1939

THE CALIFORNIA FLATHEADED BORER, *MELANOPHILA CALIFORNICA* VAN DYKE, AND THE PINE FLATHEADED BORER, *MELANOPHILA GENTILIS* LEC.

A Review of Progress of Studies Conducted at the Hackamore Field Laboratory during the Seasons of 1936-1939.

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SECTION I

PREFACE AND SUMMARY OF PROJECT TO DATE

A serious attempt to appraise the role of the California flatheaded borer in the infestation complex affecting the deteriorating east side commercial pine stands of northeastern California has been underway for eight years. This study was started by Salman in 1931 as a study of the relationships of insects infesting standing ponderosa pines. It was continued as a preliminary study of the biology of flatheaded borers by Salman and Bongberg in 1935, and was then headed up by West during the seasons of 1936, 1937, 1938 and 1939. As a result of all this work, it is considered that we now know the essential features of the life cycle and seasonal history of this insect and have considerable information on which to build for tentative consideration a general outline of its role in the ponderosa and Jeffrey pine stands in northeastern California. Certain vital points, however, have not been conclusively established, and a final report should await the outcome of several experimental jobs now underway.

Before these studies were undertaken no distinction had been made between the role of the California flathead, Melanophila californica, and the pine flathead, Melanophila gentilis. It has been necessary, therefore, to follow both species in parallel studies in order to arrive at some assignment of their relative importance. The evidence uncovered to date has shown that while these two closely related species have many similarities in habits and behavior, there is a basic difference in the larval feeding habits. The import of this difference relegates each species to an entirely distinct status in the biology of eastside pine stands. M. gentilis is concerned chiefly with dead and dying host material, and is therefore secondary in importance; M. californica attacks the living tissues of slow growing trees so as to produce perceptible injury and to this extent seems to be an insect which contributes to the deterioration of living trees and of mature stands.

It is considered that the following points brought out in this report have either been established or have sufficient supporting evidence to warrant consideration:

1. The adults of both flathead species are similar in habits.

Both have an extended flight period during the late spring and early summer and both require feeding on pine foliage to reach sexual maturity.

2. The oviposition habits and eggs are similar.

Eggs are deposited on the outer bark of living or dying trees and on slash material.

3. The feeding habits of the small larval stages differ.

Small larvae of M. californica feed in the cambium region of living trees and are associated with wart-like scars formed by wood tissues laid down over the feeding injury. This larval stage is termed the incipient stage and the resulting gallery is termed the incipient gallery.

The young larvae of M. gentilis also feed in the cambium region and produce line-like galleries in the phloem. However, there is no injury to the wood.

4. The feeding habits of the advanced larval stages have certain similarities.

During this stage both species make wide galleries in dead or dying phloem and inner bark; in thick-barked trees, both species usually enter the outer bark in the fall as prepupal larvae.

5. The change from small to fast growing larval stages differs.

M. californica larvae may remain in the incipient stage as long as the tree is living, up to four years for individual larvae; the change over to the fast growing stage comes suddenly and is associated with the change from a living to a dying or dead condition of the host material.

M. gentilis develops gradually and rapidly through the young and the fast growing stages; the entire larval development takes place in dying or dead host material.

6. The total length of the life cycle differs.

M. californica spends at least one season in the incipient stage before going into the fast growing condition; the minimum life cycle is, therefore, two years. There is evidence that two, three and even four years may be spent in the incipient stage before change over to the fast growing stage occurs.

M. gentilis completes its life cycle in one year. Eggs laid in the spring or early summer develop to new adults by the following spring.

7. Nutritional requirements of the young larval stages differ.

M. californica does not seem to be able to complete its development without spending at least one season in living host material in the incipient stage because:

(a) Repeated attempts to rear broods by forcing attacks on freshly cut green logs have been unsuccessful.

(b) Incipient broods and injuries have been established on living caged tree.
(c) The host tree cambium must be active and the host living to form incipient galleries.
(d) Incipient galleries have been present before death whenever the species has developed in dead host material.

M. gentilis readily attacks and infests freshly cut logs, dying trees and slash material and completes development in one year. It does not require a feeding period in living host material.

8. There is a difference in preferred host material.

M. californica incipient broods feed chiefly, and subsequent development takes place principally, in:

(a) Trees of slow or complacent growth.
(b) Those suffering from a setback in growing vigor.
(c) Mature, overmature or decadent trees.

The death of such trees is the factor that has created important silvicultural management and economic problems for forest administrators and lumber companies in east side forests of northeastern California.

M. gentilis prefers felled green trees, windfalls, uninfested phloem of dead trees, cull logs and slash.

PRESENT STATUS OF THE PROJECT

It is considered that sufficient evidence has been gathered on the following points:

A. The secondary importance of M. gentilis attacks on standing trees has been established. This justifies dropping that species from further consideration at this time.

B. The life history of M. californica including the following:

1. General seasonal history
2. Average or normal life history
3. Location, habits and appearance of six phases or stages of development
4. Histology of incipient galleries
5. Relation of incipient galleries to subsequent tree growth around gallery
6. Nature of incipient larval infestations
7. Length of incipient period of development

Sufficient evidence has not been gathered to clearly determine the importance of M. californica attacks on the trees. For the present, work along the following lines is comtemplated.

A. Effect of incipient galleries on tree conduction.
B. Relation of living incipient larval stages to current tree growth.
C. Initiation of the fast growing larval stage.

Work might also be done on the quantitative factor in host relations and associations of physical characteristics of tree health with the occurrence of incipient or successful flathead infestations.

IMPORTANCE OF M. CALIFORNICA

Ultimately an appraisal of the importance of M. californica in ponderosa and Jeffrey pine infestations probably will be predicated on the ability of the species to:

(a) Maintain living incipient larval populations in green trees.
(b) Produce injury that will affect those trees adversely.
(c) Through that injury contribute to poor health and death of trees.

The finding of heavy incipient populations in many green trees that have been examined in several areas and over a period of four years is ample evidence of the ability of the species to maintain larval pupulations in green trees. Preliminary experiments indicate that incipient galleries affect the tree adversely by obstructing the upward conduction of solutions in the sapwood. A high incidence of occurrence of incipient populations in trees showing characteristics of poor health has been found. To determine the importance of M. californica the chief need is to supplement the preliminary experiments by further work to determine more conclusively if incipient galleries slow down the physiological processes of the trees by obstructing conduction.

Thus preliminary results indicate that the species has the ability to maintain populations, produce injury and contribute to the poor health of trees. If supplementary studies substantiate these preliminary results, M. californica can be considered as an important factor which may, at times, be the key factor in the biological and physical complex of factors that makes up the pine beetle problem.

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SECTION II

INTRODUCTORY MATERIAL

INTRODUCTION

The purpose of this report is to bring together in one paper the result of studies on the Melanophila borers which have been conducted at the Hackamore Field Laboratory.(1) It is intended to present this material in brief style, owing to its volume, and to summarize all possible data in tabular or graphic form. The object is to make possible a review of the work in order to evoke a decision as to whether the results are to be accepted in whole or in part. It is planned to draw on the material of this paper in preparation of a Government Bulletin for publication in the future.

ACKNOWLEDGEMENTS

This project has been conducted by the direction of J. M. Miller and under the immediate supervision of K. A. Salman. Cooperation is hereby by acknowledged as follows: University of California, Forestry School, for use of microtome equipment; University of California, Department of Entomology, for use of microphotographic equipment; Regional Office and Modoc National Forest Headquarters for arrangements for CCC assistants; J. M. Miller, J. E. Patterson and K. A. Salman, for photography; H. E. Burke, for information on flathead biologies; and to S. A. Rohwer, P. N. Annand, A. S. Hoyt, F. C. Craighead, F. P. Keen and S. A. Graham, all of whom have reviewed the work in whole or in part at various times and have offered valuable criticisms and suggestions. Acknowledgement is also made to the several summer assistants who have handled much of the detailed work: D. R. Rankin in 1936, H. E. Burke, Jr. in 1937, D. P. Furman and T. L. Thompson in 1938, and R. F. Anderson and J. W. Johnson in 1939.

JUSTIFICATION OF STUDY

Recognition of the importance of the role played by flathead borers of the genus Melanophila in the losses caused by insects in the east side pine type in California has been given by Salman and Bongberg (1937) as follows:

"Very little is known of the role played by M. gentilis Lec. and M. californica V.D. in infestations of ponderosa and Jeffrey pine in California. Field men know the species as flathead borers. They make

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(1) For a description of facilities used in these studies refer to page 93.

no distinction between infestations of either species. Forest Entomologists are undecided as to which species is responsible for infestations in standing trees, felled trees, logging slash, or windfalls.

"It has been determined that the western pine beetle (Dendroctonus brevicomis Lec. is predominantly the most abundant species recorded from infested ponderosa pine trees. That species often does not seem to be the primary entomological cause of death of infested trees. The same thing may be said of the Jeffrey pine beetle (D. jeffreyi Hopk.) in Jeffrey pine. In recent years, flathead borer infestations have been recognized as important elements in the infestation of both host species. In many of the trees that have been examined, flathead borers seemed to have played a primary role in the succession of attacks of the several species of insects that have been involved in the death of the tree."

Further justification has been stated in a report by the writer (West, 1937) as follows:

"To properly interpret insect losses, attention must be given to all the factors involved. No one organism can rightly be construed to be the sole cause of the damage. Even where a single insect species is involved, the effect of other factors such as climate, physiography and ecology cannot be overlooked. In the case of beetle depredations in the forests of California, where more than one species is concerned, proper evaluation of the role played by each species must be established. Heretofore, little attention has been given to species other than Dendroctonus, since the latter are the species present in the majority of cases where basal analyses of dead or dying trees are made."

OBJECTIVES

The objective of the studies conducted during the past three years has been to secure information concerning the biology and host relationshop of the Melanophila borers as a basis for evaluating their position in the forest insect complex of the east side pine type in California. Study was first confined chiefly to the biology of the species. Since rearing studies by Bongberg, in 1934 and 1935, had shown that M. californica was the species associated with the death of standing trees, attention to that species was stressed, and the studies of M. gentilis have been largely incidental. In the course of biological studies, which naturally brings in the field of host relationships, certain "leads" have resulted. These leads might well be followed in the future in attempting to evaluate the role of the species. Studies in host relationships have by no means been carried far enough to permit a complete definition of the role.

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SECTION III

REFERENCES AND TAXONOMY

LITERATURE

A review of the literature dealing with the biologies and host relationships of Melanophila species revealed a dearth of information. Little has been added to the notes of Burke (1917, 1919). Burke believed that most flathead borers had one generation a year, although individuals of the same brood might require a longer period of development. He wrote that M. gentilis was very injurious to second growth timber, but could also attack and kill mature trees. That species was considered one of the most injurious enemies of its host species. M. californica was considered to be of equal importance in second growth timber. Its role in the infestation of mature trees was chiefly considered to be that of supplementing attacks by other species.

Keen (1929) wrote that M. gentilis was apparently responsible for the death of many pines, particularly in the Sierras. He more recently relegated greater importance to the species in stands situated on rocky slopes where soil moisture conditions were unfavorable, and mentioned that M. californica was a very destructive factor in pine stands in southwestern Oregon and northeastern California. Since the initiation of the present studies, Keen (1938) has restated his conception of the importance of the two species. M. gentilis was considered as a secondary infestation when occurring in the bole of standing trees, and the possible importance of M. californica in weak, decadent trees was recognized.

UNPUBLISHED NOTES

Unpublished notes in the collection files of the Berkeley Station have been summarized by Salman and Bongberg (1937). These notes indicate the following:

"a. Both species are attracted to pine foliage.
b. Both species are attracted to slash and felled trees.
c. Gentilis appears to be the species chiefly concerned in infestations of felled trees, logs, windfalls and injured trees, and in secondary bole infestations in standing trees.
d. Californica seems to be the species chiefly concerned in infestations of standing trees, although attacks by that species also sometimes seem to be of secondary importance."

PREVIOUS WORK

During the seasons of 1934 and 1935, study of Melanophila species, chiefly limited to emergence rearing, was conducted at the Hackamore Field Laboratory by J. W. Bongberg. In the following pages any reference to data secured during those years relates to Bongberg's work.

TAXONOMY

Both species of flatheads under consideration belong to the order Coleoptera, family Buprestidae, and sub-family Buprestini (Leng, 1930). Sloop (1935) places both species in Obenberger's group Phaenops. According to Sloop that group is a sub-genus, separated from Melanophila (Melanophila) by the absence of sensory pits contiguous to the lateral margins of the middle coxal cavities.

Adults

There is a considerable variation in adults, particularly in the case of M. californica. Most specimens, however, can be accurately identified in the field on the basis of color differences.

M. gentilis, described by LeConte in 1863, is the larger of the two species. The color is bright green; elytra immaculate; antennae extend beyond the caudal margins of the prothorax; third segment of antennae is almost as long as the first and second segments taken together; and pronotum is widest in front of the middle.

Van Dyke described the adults of M. californica in 1918. Their color is dark, usually being of a brown shade, elytra usually maculate with three yellow spots on each elytron, definite maculations not always visible, antennae extend to the hind angles of the pronotum, third antennal segment about twice as long as the second and distinctly longer than the first, pronotum widest at the base.

Observations on more than four thousand adults of M. californica has revealed a consistently wide variation in maculations. Color of the ventral side is a valuable criterion in separating the two species. M. californica is distinctly green on the venter, while M. gentilis is distinctly coppery. Adults of M. californica are shown in Figure 1.

Larvae

Typical larvae are shown in Figure 4.

Burke (1917) published a key for the separation of larvae of Melanophila from other genera of Buprestidae. The writer knows of no key

to the larval stages of species of Melanophila. DeLeon (1935) tentatively separated the two species as follows:

"Groove dividing ventral plate (prothorax) extending to anterior margin; roughenings of dorsal (prothoracic) plate unevenly spaced; labium broad, usually emarginate . . . . . gentilis.

"Groove of ventral plate not extending to anterior margin; roughenings of dorsal plate rather evenly spaced; labium narrow, usually evenly rounded . . . . . californica."

During the winter of 1937-1938 a series of larvae of both species, identified through rearings, were submitted for study to Mont A. Cazier, of the University of California, Department of Entomology. His study apparently showed that DeLeon's separation distinguished larvae of active and prepupal stages rather than separating species. During the conduction of the work herein reported, no taxonomic differences have been noted by which larvae could be separated in the field. There are, no doubt, such differences, very possibly of such a minute type as to preclude their use in field work. At the present time it is possible to separate the species in the field, under some conditions, on the basis of association of larvae with two distinct types of galleries. A series of larval specimens is being prepared for submission to the Division of Insect Identification for study.

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SECTION IV

LIFE HISTORY

DESCRIPTION OF STAGES

For the purposes of clarifying the following discussion on Seasonal History and Habits, a brief definition and description of the several stages follows:

Adults

Adults of M. californica are shown in Figure 1. The length of body of male and female of both species has been measured for a large series of individuals. A summary of the measurements is presented in Graph 1a (californica) and Graph 1b (gentilis). Californica is the smaller of the two species, with 238 males averaging 8.8 millimeters in length, and 231 females averaging 9.7 millimeters. For gentilis the corresponding figures on 124 males and 64 females were 10.7 and 11.4 millimeters respectively.

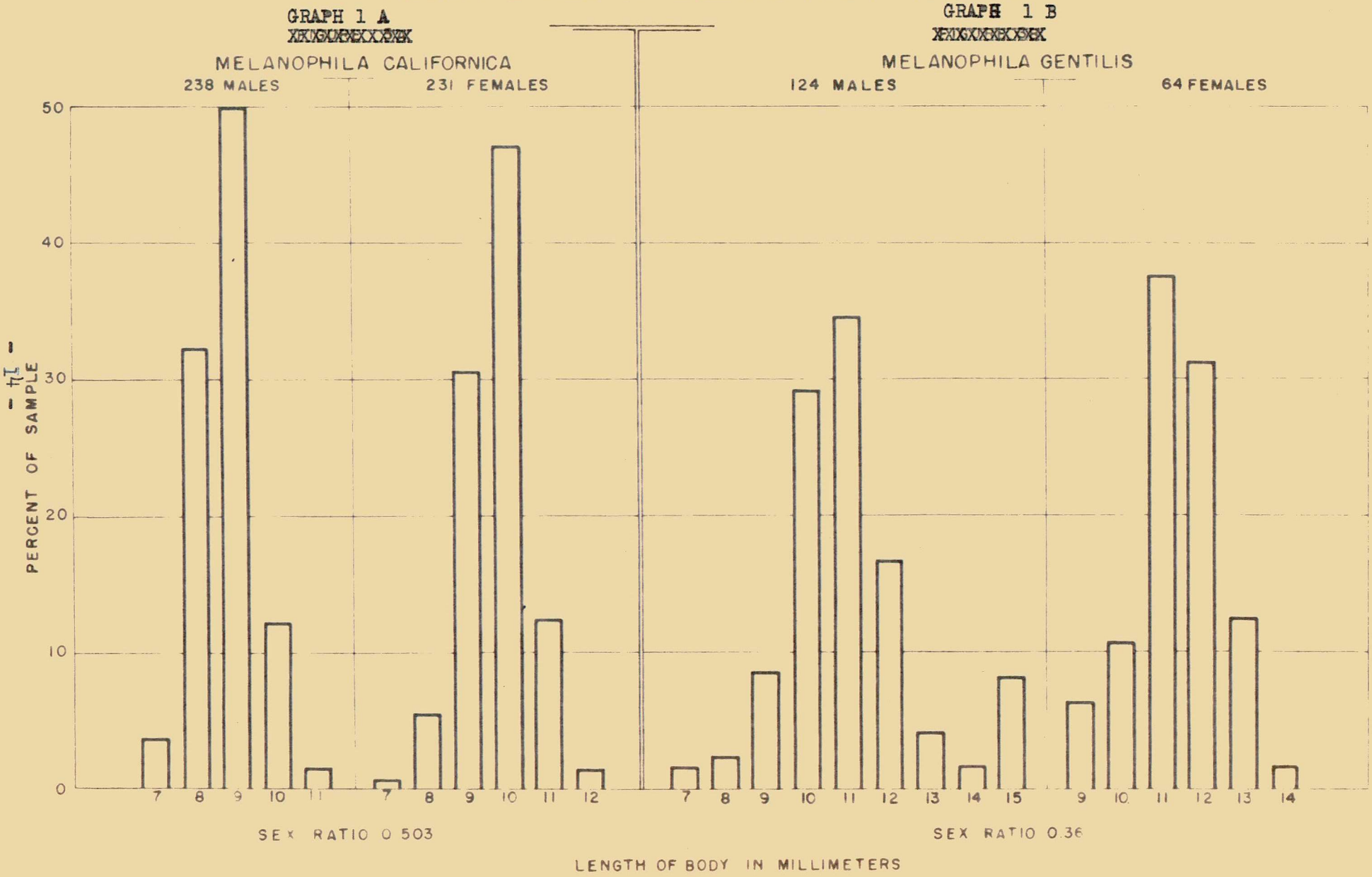
Egg

There has been no previous mention of eggs of these species, either in the literature or in the large number of notes by Burke, Hartman and others at the Berkeley Station. In 1937, for the first time eggs of both species were found by observing oviposition. The following description suffices for eggs of both species: eggs whitish, opaque and soft-bodied; roughly flattened and pear to oval-shaped in outline; dimensions approximately 1 millimeter in length and 2/3 of a millimeter in width. (Figure 2.)

Young Larvae

The term "incipient" has been chosen by the Berkeley Station to designate the young, small larvae of M. californica living in the cambium region of green trees and associated with galleries in the wood. This term is also applied to the galleries themselves which are characterized by warty healing of the wood over the path of feeding of the larvae. Since feeding occurs in the cambium region, there is also injury to the phloem, which remains less evident after healing. Galleries are shown in Figures 3, 6, 18 and 19. Although these galleries have been noted over a period of years, little attention had been paid to them prior to 1936. Larvae found in these galleries range up to 5 or 6 millimeters in length.

RELATIVE SIZE OF MELANOPHILA ADULTS



Young larvae of M. gentilis of similar size are associated with line-like galleries in the phloem. These galleries can sometimes be traced on the wood surface as the result of clinging particles of frass, but there is no actual injury to the wood itself. A comparison of larval galleries is given in Figures 8 and 9.

Separation of infestations of the two species has been successfully made by association with these distinct types of galleries. The presence of healed incipient galleries is fairly positive evidence that brood of M. californica is present. There are, of course, trees in which the incipient californica larval brood has been entirely unsuccessful and has died. In the fall of 1937 three felled trees were classified as having brood of M. gentilis on the basis of presence of line-like galleries in the phloem. Gentilis adults were reared from bark of all three trees during 1938.

Fast Growing Larvae

The term "fast growing" has been applied to the individuals in that stage between the incipient (M. californica) or small larval stage (M. gentilis) and the prepupal stage (Figure 4). It is called the fast growing stage because of the rapid increase in size of larvae of both species as they feed outward through the phloem, forming typical flathead galleries. A comparison of the incipient and fast growing stages of M. californica is given in Figures 6 and 7.

Prepupae

Prepupa is the name given to the overwintering, resting stage of larval development common to both species. Prepupae are normally found in U-shaped positions in bark cells (Figure 5). The body of the prepupa is considerably shortened and thickened as compared with the developing larva in the phloem, and is distinctly creamy in color.

Pupae

Pupae are usually found in bark cells where they have passed the winter as prepupae. However, in thin-barked host material prepupal larvae may overwinter and pupation may occur in cells in the wood. (see Figure 12).

SEASONAL HISTORY

As previously mentioned, chief emphasis in these studies has been placed on M. californica, and in many cases the acquiring of facts

concerning M. gentilis has been incidental. This discussion has been started with the prepupal stage primarily for convenience in presenting a somewhat complex life cycle.

Prepupal Stage

The prepupal stage may be initiated from the end of July to the advent of cold weather in the fall. Observations on the initiation of this stage have been made in some 40 odd logs used in rearing studies, in 100 or more trees in the field which have been felled for brood or composition study, and in numerous lots of slash. This is the normal overwintering stage of both species and has the nature of an enforced diapause. In all material of whatever source in which prepupal brood was found in the fall of the year, no emergence occurred until the following spring.

To test the nature of this diapause, 50 prepupal individuals of M. californica were reared at room temperature (about 72° F) during the fall and winter of 1936-1937. The first pupation occurred in March and adults were formed about a month later. As will be seen in the discussion of pupae, the time of pupation was very little advanced by this attempted "forcing". After passing the winter, prepupae may be found as late in the season as the first part of July.

In 1937 prepupal brood bark containing both species was placed in a cellar in the spring of the year and held over until 1938 at subdevelopmental temperatures. This prolonged the prepupal stage a complete year. In 1938 from 16 square feet of bark there was an emergence of .75 adults of M. californica and 112 adults of M. gentilis per square foot of bark.

Herbert's unusual record of gentilis remaining two years in transition from prepupal to adult stage is noted by Salman and Bongberg (1937).

Pupation

The pupal stage is initiated in the spring of the year with the advent of warm weather, generally beginning in the latter part of April or the first part of May. In 1937 pupae of M. californica were first observed in the field during the first week of May while pupae of M. gentilis were found on April 22. Pupation of M. gentilis generally tends to occur somewhat earlier, probably because of the fact that brood is generally found in down material which receives more heat from the sun. Emergence of M. californica began during the first part of June, indicating a pupal period of approximately one month. Field observations on 6 standing trees in 1938 also indicated the same pupal period for californica.

An attempt was made in 1938 to rear individual prepupae through to the adult stage at air temperature. High mortality was attributable to the handling of individuals and disturbance of normal environment. The average length of pupation for eight individuals of M. californica was 30.4 days, with a maximum of 35 days and a minimum of 24. In addition, 10 pupae which were reared to the adult stage indicated that the average length of the pupal period was at least 28.9 days, ranging from 22 to 37 days. The length of the pupal period would of course, be considerably influenced by factors such as temperature, exposure, occurrence in down or standing material, or on the north or south side of tree, in shade, etc. In 1937 the average pupal period of 37 individuals at 85° F. constant temperature was only 9 days.

Emergence

Emergence records have, for the most part, been based on bark rearings at the laboratory, supplemented by field observations. Various types of brood material have been reared in varying amounts during the several seasons of investigations. Hence the emergence dates are general ones. Table I gives the dates of start, peak and end of emergence of M. californica for the period 1934-1939. In 1937 and 1938 smaller amounts of M. gentilis brood bark in rearing indicated that emergence follows the same general trend as does that of M. californica, although tending to occur somewhat earlier. The peak of gentilis emergence in 1937 was reached at the end of June while that of californica occurred in mid-July. Such variation as is shown would, of course, be expected.

Table I

EMERGENCE PERIOD - MELANOPHILA CALIFORNICA
(From rearing can records)

Year	First Emergence	Peak of Emergence	Last Emergence
1934	May 7	July 2	August 2
1935	Before June 17	July 17	August 26
1936	Before June 11	June 22	August 3
1937	May 22	July 16	August 17
1938	June 1	July 8	July 27
1939	Before May 15	July 7	July 23

In 1938 field counts were made on six standing brood (M. californica) trees. No emergence was recorded on May 23, while 36 percent of the brood had emerged on June 14. Reared bark emergence began on June 1.

The progression of seasonal development of californica brood in standing trees in 1938 is shown in Table II

Table II

SEASONAL DEVELOPMENT OF EMERGING BROOD FROM STANDING TREES - 1938
(Basis - 6 trees)

Date	Area of Sample (sq. ft.)	Percent of Total Brood			
		Prepupae	Pupae	Adults	Emerged
5/23/38	3.13	34.8	60.9	4.3	0
6/14/38	9.50	2.3	45.5	15.9	36.4
6/20/38	6.25	2.7	33.3	16.0	48.0
6/28/38	7.16	1.6	7.8	21.9	68.8
7/5/38	7.50	5.5	6.8	5.5	82.2
7/12/38	6.00	5.7	1.4	5.7	87.1

Egg Stage

Eggs are found during the period of adult activity. Since they are located in the field only with considerable difficulty, practically all egg studies have been conducted with caged material. As would be expected, the greatest number of eggs was found following the peak of emergence in any one year. For 175 eggs of M. californica reared at air temperature in 1938, the average length of incubation was 13.3 days with a maximum of 19 days and a minimum of 9 days. The distribution of individuals according to the length of the incubation period is shown in Graph 2a. Graph 2b gives similar data for M. gentilis. 77 eggs had an average length of incubation of 12.2 days, ranging from 7 to 22.

Young Incipient Larval Stage

Hatching occurs through the side of the egg. After leaving the egg the newly hatched larvae of M. californica mine diagonally through the bark and phloem to reach the cambium region. In several cases the complete gallery has been traced from the larva backward through the bark to the egg. The incipient larval stage of M. californica broods begins after the larva has reached the region of the cambium.

LENGTH OF EGG STAGE WHEN EXPOSED TO AIR TEMPERATURES

GRAPH 2 A

[redacted]

MELANOPHILA CALIFORNICA

175 EGGS

AVERAGE - 13.3 DAYS

GRAPH 2 B

[redacted]

MELANOPHILA GENTILIS

77 EGGS

AVERAGE 12.2 DAYS

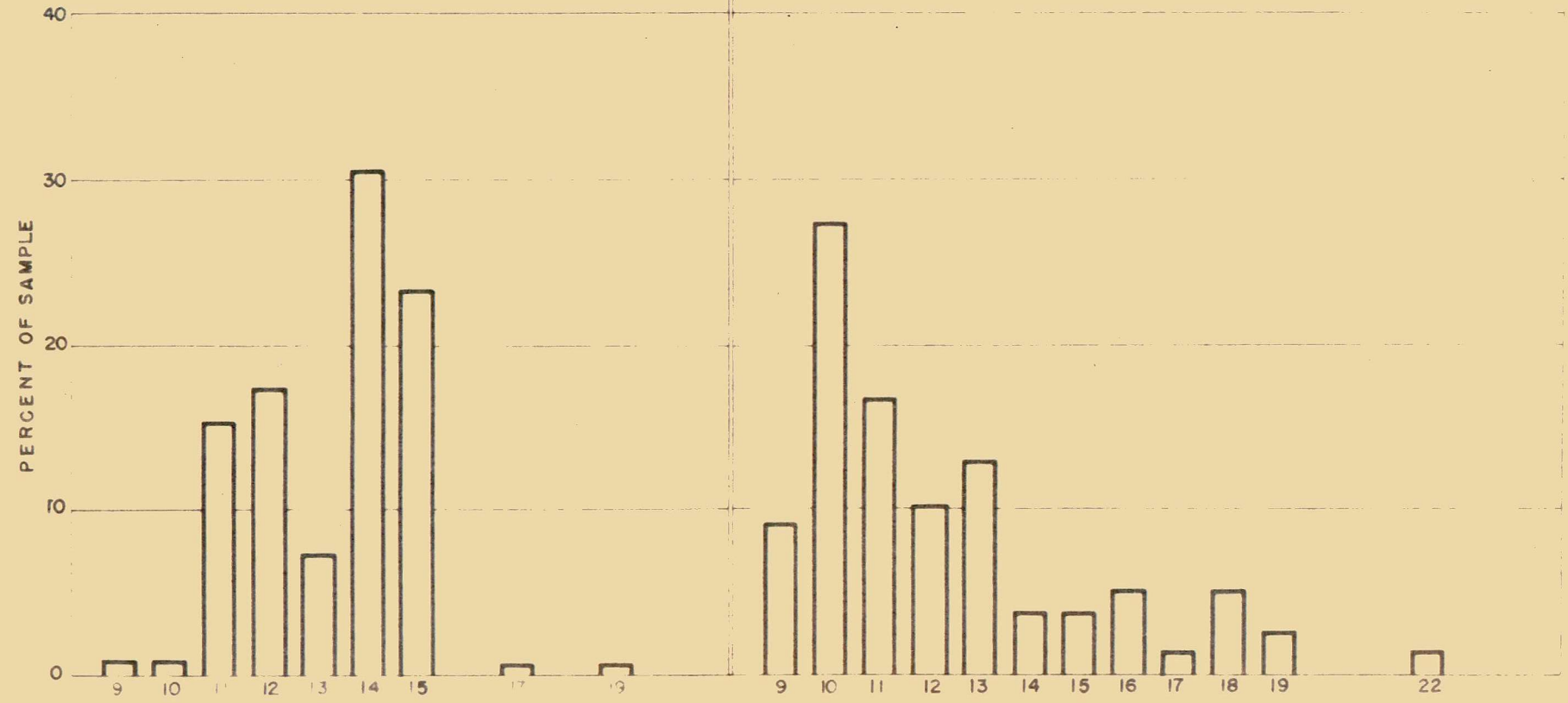


Table III

DEVELOPMENT OF LARVAE OF MELANOPHILA CALIFORNICA IN LOGS

Number	Date of Sampling	Area sampled sq.in.	Total number larvae	No. Alive	No. Dead	Incipients				Assoc. with pitch blister or pitched out	Medium larvae	Large larvae in phloem-bark	Prepupae in bark
						Successful	Unsuccessful 1935	Unsuccessful 1936	Unsuccessful Total				
Log 13	6/13/36	39	16	8	8	8		8	8				
	6/20/36	22.5	3	2	1	2	7	1	8	1			
	7/1/36	30	1	1		1*	9	4	13	1			
	7/9/36	100	8	2	6	2	2	6	8	6			
	7/24/36	38	1	1		1*	2°+1		3	1			
	7/31/36	28	1	1			5					1	
	8/7/36	28					4						
	8/14/36	36	1	1								1	
	8/21/36	25										( )	
	8/28/36	24	3	3			1						2
Logs 25 -1- & -2- in alternate weeks	7/2/36	407	31	27	4	27	5	4	9				
	7/10/36	30	8	6	2	6	1	2	3				
	7/16/36	16	1+(1)		1			1			(1)		
	7/24/36	16	4	4							4		
	7/31/36	16	(3)	(3)								(3)	
	8/7/36	16	4	4								4	
	8/14/36	16	2	2								2	
	8/21/36	16	2	2								1	1
	8/28/36	16	2	2									2
	9/4/36	22	1	1									1
Logs 25 -4- & -5- in alternate weeks	7/2/36	316	29	27	2	27	4	2	6	3			
	7/6/36	305	25	23	2	23	4	2	6	3			
	7/10/36	20	3	1	2	1	1	2	3	3			
	7/16/36	16	1+(2)	1							1+(2)		
	7/24/36	16	2	2							1	1	
	7/31/36	16	1+(3)	1			1		1			1+(3)	
	8/7/36	16	2	2								2	
	8/14/36	16	2	2								2	
	8/21/36	16	1	1									1
	8/28/36	16	1	1								1	

Legend: *Beginning to widen gallery °Older than 1935 ( ) galleries - larvae not found

The first, newly established incipient larvae are usually found beginning in July, and heavy broods are not found until the end of July. As will be shown in following pages, these incipient larvae may live for several years before entering the fast growing stage. Since the length of this period is indeterminate, but continues for at least a year, incipient broods are found in the trees at all seasons of the year.

The young larval stage of M. gentilis is of brief duration, occurring during that period when incipient broods of californica are becoming established.

Fast Growing Larval Stage

This stage of development has been observed in M. californica broods in the field from early June on. It has been initiated in logs cut for rearing studies at all times during the warm season. Normally, larvae entering the fast growing stage reach the prepupal condition before the advent of cold weather. Table III gives samples of the rate of larval development in logs in rearing.

In 1936, three logs were cut from an incipient brood tree on September 17. This brood did not reach the prepupal stage and but very few fast growing larvae lived over the winter. Development of those few larvae did not continue the following spring, possibly due to mold invasion.

Occasionally brood may enter the winter as partially grown larvae. Field observations on some 20 felled trees, and on several standing trees during the past winter indicate that fast growing larvae do not successfully overwinter. Although a few larvae may live over the winter their development is inhibited in the spring, possibly because of the unsuitable condition of host material.

Table IV indicates the number of logs, cut from green trees, which were used in study of brood development, and shows in what number of logs studies were carried through to emergence. Contamination by other insect species was in many cases responsible for dropping the logs from the study.

Table IV

RECORD OF LOGS REARED - LOGS FROM FRESHLY CUT TREES CONTAINING INCIPIENT BROODS FOR OBSERVATIONS OF LARVAL DEVELOPMENT

Number of logs in which the several stages of development were observed.

Rearing Season	Incipients	Growing Larvae	Prepupae	Lived Overwinter	Pupae	Emergence
1936	35	37	28	27	22	16
1937	21	21	14	9	5	4
Total	56	58	42	36	27	20

The fast growing stage of larvae of M. gentilis is entered, and generally completed during the same season in which the eggs were deposited on the host material.

LENGTH OF LIFE CYCLE

The length of life cycle of the California flatheaded borer is two or more years. Subsequent discussion will point out the necessity of at least a year of development in the incipient stage. It has been shown that practically a full year is required for development from incipient to adult. Since the incipient larvae may be from one to four years old at the time the fast growing stage begins the complete life cycle may require from two to five years. Population figures show that there is a large reduction between incipient and adult stage, all of which is not accounted for by woodpecker predation. Once the fast growing stage has started, it is difficult to trace back to the individual larval incipient galleries. It is not yet known if all ages of larvae are equally successful in developing through the fast growing stage to the prepupal condition.

The question of the possibility of a one-year life cycle is naturally an important one. It is the writer's belief that the points made under the discussion of the necessity of a period of incipient development, in the following section of this report, adequately demonstrates the improbability of a one-year life cycle. M. californica is an insect, part of whose development is associated with living host material. The results of studies are sufficient to demonstrate that at least a two year life cycle is the normal course of development for the species.

The seasonal development and life cycle of M. californica is shown in Figure 10.

M. gentilis has a one year life cycle. Forced attack studies and trap tree records show that adults emerge one year from the time the eggs are laid. (See Table XI.)

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SECTION V

THE INCIPIENT STAGE

Considerable attention has been given to the incipient larval stage of Melanophila californica and to the gallery or ridge formed by the growth of the tree over the tissues injured by the larval feeding. The reasons for that consideration and interest are as follows:

1. The incipient larval stage appears to be an unusual type.
2. A determination of the primariness of the flathead borer attack is largely dependent on the interpretation given to the role of the incipient stage in the living tree.

NATURE OF INCIPIENT GALLERY

Gross Description

Incipient galleries have been described as winding, warty ridges, and are shown in Figures 3 and 6. The actual gallery itself is, technically speaking, visible but a short distance behind the spot where the larva is feeding. The ridge has been formed by healing of the wound made by the larva. There is no set length to the galleries, and their course can only be said to be roughly horizontal. The "active" end of the gallery may be associated with a living larva, with a minor "pitch-fleck", or with a "pitch-blister" of variable size (Figure 11).

Contrast with Galleries of Other Cambium Miners

In the writer's report (1937a) the statement was made that there was a scarcity of literature dealing with incipient galleries and certain references were called to his attention. Since that report appeared, these have been checked. Other than a reference by Hopkins (1899) to Melanophila attacks in fir, nowhere in the literature has the writer found reference to healed galleries in the wood as being an integral part of the development of a cambium mining species. Scars in the wood resulting from larval activity are, of course, of rather common occurrence. A recently suggested footnote to a paper prepared by the writer for presentation at the American Association for the Advancement of Science meetings at Stanford University during June, 1939, brought out this fact in the following statement:

"Although 'incipient attacks' are rarely referred to in literature with any degree of definiteness such as an actual term, this feature is well known among entomologists as characteristic of the work

of many Buprestids attacking living trees, such as:

"Chrysobothris tranquebarica Gmelin in casuarina in Florida
" femorata in hardwoods and fruit trees
" mali in fruit trees
Agrilus anxius in poplars and birch
" bilineatus in oak and chestnut. In some cases these are figured.
It is also characteristic of some cerambycids, as:
Clycobius speciosus Say in sugar maple
Goes spp. in oak, hickory, and many other trees.
Romaleum spp. in oak
Tetropium abietis in fir
_____ in incense cedar

"In literature these early galleries have been considered unsuccessful attacks, the result of the inability of the larvae to overcome the resistance of the tree."

The last sentence in the above quotation is important for it brings out the essential difference between the insects mentioned and M. californica. In the latter species these galleries may be considered unsuccessful attacks as long as development does not go beyond the incipient stage, but, paradoxically, this stage seems to be necessary for the successful completion of the life cycle.

HISTOLOGICAL CHARACTERISTICS

During the winter of 1936-1937 a technical study of the nature of incipient flathead galleries was made. This involved preparation of 100 slide mounts of gallery material. For details, refer to the report submitted by the writer (West, 1937d). The following summary is taken from that paper:

"The following salient features characterize incipient flathead galleries:

"1. A light flow of resin occurs at the point where the larva is feeding.
"2. This resin flow spreads either side of the actual point of injury.
"3. The lesioned area heals over in the wake of the larva. There is an area of abnormal tissue peripheral of which the wood structure is again normal. The following points characterize this healing:

a. The proliferation of parenchymatous tissue is the first response to the injury. This tissue becomes infiltrated with resin.
b. The continuity of the medullary rays is broken by this area of parenchymatous tissue, and the rays themselves may become infiltrated with resin.

"c. Peripheral to the parenchymatous tissue wood tracheids are again laid down. There may be a zone in which the cells are transitional between parenchyma and tracheids, and in some cases the first tracheids are horizontally disposed.

d. Growth at the point of injury may be less than normal. often in such cases growth in the following year is greater than normal so that the line of growth is evened up.

e. An abnormal abundance of resin ducts may develop immediately peripheral to the lesion.

f. The gallery may end in the formation of a pitch blister."

Microphotographs of galleries are shown in Figures 21, 22, 23, 24.

Relation to Subsequent Growth

The occurrence of subsequent growth over injured areas is an important phase of the incipient problem. Briefly the writer's conception is as follows: The actual point of injury is covered with a band of parenchymatous tissue; peripheral to this tracheids once more appear; in some cases these tracheids are not entirely normal; in all cases that have been examined the limits of annual rings can be told in the region lying over the gallery; the designation of annual rings is based on tracing them to either side of the point of injury into areas of normal growth. The ability to read this growth record is of course the basis for determining the the age of incipient larvae. Figure 20 illustrates the relation of an incipient mine to annual growth rings.

To check this conception of subsequent growth additional examinations have recently been made. The writer feels convinced that the number of rings laid down peripheral to the point of injury can be told. There are, of course, certain trees in which the growth is extremely complacent, making it impossible to count growth rings without preparing a slide mount for examination under high power magnification. Even in such cases it is possible to see, with low power magnification, that growth rings do occur peripheral to the point of injury.

Effect on Conduction

Another important consideration is the possible effect of incipient galleries on conduction. It is the writer's impression that the outer few rings of a tree are generally considered the active ones in conduction. It is these outer few rings that are disturbed as the result of incipient gallery formation. An individual gallery in itself does not seem significant. It must be considered, however, that the sum total of galleries presents a considerable amount of abnormal tissue in the line of conduction (Figure 25).

Recently some 33 tests have been run with the injection of small blocks of wood in which an incipient gallery cuts across the face. The results of these few tests indicate definitely that there is some interference of conduction by the gallery. In some cases there was no conduction beyond the gallery in the line of the extent of abnormal tissue. In some of the tests in other cases and over a period of time there was evidence of lateral conduction, which we know occurs along the medullary rays, so that only the immediate vicinity of the gallery finally remained uninjected. This might indicate that the effect of galleries would be to slow up conduction, although not necessarily stop it.

Here, again, it is emphasized that this work is considered merely as giving a good lead to follow. In continued work this season, it is planned to standardize the procedure of injecting such blocks, make a large series of tests and study the results in detail.

Nature of Incipient Infestations

Incipient infestations are characterized by successive attacks often evident over a period of years. In some trees attacks are obviously more successful than in others. Death of incipients must be interpreted as being due to some factor of host resistance. "Pitching-out" frequently seems to be the immediate cause of death. As pointed out in the writer's study of the nature of incipient galleries, a greater than normal abundance of resin ducts is frequently found in association with incipient galleries. In coniferous trees extra resin duct formation is a typical response to injury.

The fluctuation in relative abundance of the several broods of incipient larvae in standing trees may result from various factors. In 1938 a cold wet spell during the first week in July considerably curbed adult activity as evidenced by field observations and the reaction of adults in cages. This period came at the peak of emergence and hence undoubtedly had considerable effect on oviposition during that season. In the fall of the year, samples of standing trees showed very few larvae of 1938 origin were present. This same wet period was possibly responsible for the failure of many broods of fast growing larvae to reach the prepupal stage. Hence the 1939 emergence was less than would normally have occurred. This would mean fewer adults in 1939 and again a smaller population of incipients to be established this season.

It is entirely possible that the growth in any one season could have some effect on the success of incipients, particularly on larvae of the then current season.

The Quantitative Factor in Host Relations

A lead which would bear investigating concerns the population of incipient galleries. A series of twenty standing trees was sampled beginning in 1936. In one tree D.b. had already entered the picture

obscuring the flathead element. Of nineteen trees, nine have since died, including one tree in which the larvae had entered the fast growing stage when sampling was begun. The average incipient population for each tree over the period of sampling is given in Table V.

Table V

INCIPIENT POPULATIONS IN STANDING TREES
(From basal samples.)

Tree Number	Period of Sampling	Sample area (sq. ft.)	Successful Incipients per sq.ft.	Remarks
36-1	7/7-24/36	.25	12.00	Died
36-2	7/24/36	.19	5.26	
36-3	7/9-8/24/36	.92	22.83	Died
36-4	7/9/36-8/5/37	.97	5.15	
36-5	7/9/36-8/5/37	1.36	8.82	
36-6	7/9/36-8/5/37	1.26	10.32	Died
36-7	7/10/36-8/11/37	2.34	10.26	Died
36-8	7/10/36-10/28/38	3.03	3.96	
36-9	7/10/36-10/28/38	3.22	3.73	
36-10	7/10/36-8/31/36	2.19	15.07	Died
36-11	7/17/36	12.13	34.62	Tree dying, fast growing larvae at time of first examination.
36-12	7/10/36-8/11/37	2.51	17.53	Died
36-13	7/24/36-8/31/36	.92	17.39	Died
36-14				Contaminated
36-15	7/31/36-10/28-38	1.85	.54	
36-16	7/31/36-10/28-38	1.77	2.82	
36-17	7/31/36-10/28-38	2.06	4.37	
36-18	7/31/36-8/11/37	1.46	10.96	
36-19	7/31/36-10/28/38	1.72	1.74	
36-20	7/31/36-10/28/38	1.78	18.54	Died
Average			10.84	
Average of trees that died			17.64	
Average of trees that remained alive			5.89	

A most interesting relation is apparent. For the trees which have remained alive the incipient population averages 5.89 larvae per square foot, ranging in individual trees from .54 to 10.96. For the trees which have died the average is 17.64, ranging from 10.26 to 34.62. Possibly there is a quantitative factor in the relation of incipients to the host tree.

The amount of sampling is greater in the trees which have remained alive. Hence the effect of mechanical injury can be ignored.

Length of Incipimnt Period of Development

The determination of the length of incipient period of development is based on a study of the galleries associated with the larvae. As pointed out in the discussion of the nature of incipient galleries, the wood heals over behind the feeding of the larva leaving a permanent record of incipient attack. Determination of the age of a larva is based on counting the number of growth rings overlying the point of origin of the gallery. It should be pointed out that the determination of the age of larvae, based on the nature of growth overlying the wound is founded not on a small amount of material, but on the examination of several hundred galleries over a period of three years. Table VI presents an example of the age distribution of larvae in a sample of logs from three trees. As would be expected, there is an inverse relationship of abundance to age. Living larvae were found to be from one to four years old. There have been one or two cases where larvae apparently were five years old.

Table VI

INCIPIENT LARVAE BROODS IN A SINGLE STEM

Sample	Year of Origin of Living Incipient Larvae							
	1934		1935		1936		1937	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
1			3	7	9	21	30	72
2	9	33	6	22	1	4	11	41
3			12	25	15	31	21	44
Total	9	8	21	18	25	21	62	53

For the same logs, mortality for the current season was determined when dead larvae were found in association with the galleries. The mortality figures are presented in Table VII. The indication is that mortality apparently affects all ages of larvae approximately equally.

Table VII

1936-1937 MORTALITY OF INCIPIENT BROODS

Sample	Year of Origin of Brood								
	1935			1936			1937		
	No. larvae		Percent	No. larvae		Percent	No. larvae		Percent
	Alive	Dead	Mort.	Alive	Dead	Mort.	Alive	Dead	mort.
1	3	3	50	9	4	30	30	1	3
2	6	3	33	1	3	75	11	4	27
3	12	3	20	15	6	29	21	20	49
Total	21	9	30	25	13	34	62	25	29

Necessity of at least a One-Year Incipient Stage

The work of three seasons has shown that M. californica cannot develop without at least a year of development as incipient larvae, and this incipient stage of development is, of course, possible only in a standing living tree. This is an extremely important point in the life cycle of the species. The following points adequately justify this conclusion:

1. In all cases where M. californica has emerged, incipient galleries have been found in the host material. These galleries can only have been formed in the living tree. Development beyond the incipient stage can only have occurred in the dead or dying tree, or a portion of it. These two phases of development cannot occur in a single season. By the time eggs are laid the proliferation of spring wood is largely completed. In order that galleries may have been formed, the incipient development must have started at least a season previous to the fast growing stage. These observations apply to more than 100 lots of host material which have been examined in adult rearing work over the past four seasons, as well as to more than 300 trees examined in the field in connection with composition and other studies. In addition, more than 50 logs containing incipient broods have been followed in rearing studies. In 20 of these logs in which rearing was carried through to the adult stage, a year was required.

2. Eggs of both species have been observed placed on green trap trees (which constitutes dead host material). 64 square feet of bark from various portions of 5 trap trees produced .2 adults of M. gentilis per square foot, the following year, but there was no emergence of californica, and no unemerged brood remained in the bark samples.

3. In forced attack cage experiments, eggs of both species have been laid on logs and poles and larvae have started mining in the phloem. However, gentilis is the only species successfully reared to the adult stage from such material. Californica larval broods did not successfully overwinter in this material. The amount of material for californica studies included 6 logs and 7 poles in 1937, and 9 logs and 24 poles in 1938, including only material where foliage was furnished in the cage. For a complete record of forced attacks refer to Tables X and XI.

4. In forced attack studies on standing caged trees, incipient larvae have become established and have lived overwinter. A discussion of caged tree experiments and of figures on the tree which has been felled is given under Forced Attacks.

5. There is some indication that the food of incipient larvae may be the newly formed wood of each season, which would explain the inability of larvae to develop on dead material. A discussion of this theory is given under the section on incipients in relation to growth.

Incipients in Relation to Growth

The possible importance of growth in relation to the presence of flathead incipient infestations has been stressed. In the past there has been the rather definite impression that incipient infestations are associated with poor growth and in many cases with the loss of annual rings. Initial study of growth rings has been started during the 1939 season. On the basis of about 25 examinations that have been made to date, it is apparent that flatheads are associated with poorly growing trees. However, it is also indicated that successful incipient flatheads are associated with continuous annual growth. Six living pine poles with incipient infestations, taken from the Timber Mountain region, all had complete growth records; four trees which died in 1938 and in which flatheads were the only major successful insect species also had complete growth records up to the year of death; three trees which were attacked by D.b. but supported flathead incipient broods had complete growth records; one windfall had very heavy unsuccessful incipient galleries and an incomplete growth record; another tree, which died in 1938 on the Timber Mountain plot as the result of D.b. infestation, had a few, scattered unsuccessful incipient galleries and an incomplete growth record; eight trees from the Lassen National Forest in which incipients were predicted, but were not found, had incomplete growth records; another Lassen tree in which larvae had just entered the fast growing stage this summer had a complete growth record through 1938.

It is emphasized that this relationship is not stated for a fact, but merely as a lead which, it is believed, would be well worth investigating. The idea in itself, would seem rational. It would mean that the food of incipient larvae is the newly formed annual growth. It would explain why M. californica cannot attack and develop in material such as slash. It might also explain why certain trees which are classed as high risk do not support living incipient flathead broods; namely because they are not putting on growth.

For the immediate future it is planned to secure a larger series of cores or preferably chips from trees which are supporting incipient flathead broods. In all cases where incipients are present the gallery heals over behind the larva. This could not occur if the tree were not putting on an annual ring unless growth occurred only at the point of injury.

EXPERIMENTS TO ESTABLISH INFESTATIONS

Caged Tree Studies

During the season of 1936 three small trees were completely caged as described under Facilities. One of these cages is shown in Figure 15. These trees were selected as representing a poor specimen (IV), a good specimen (V), and an average specimen (VI). The intro-

duction of beetles to these cages is given in Table VIII.

Table VIII

INTRODUCTION OF BEETLES TO TREE CAGES
(Number of adults - M. californica)

Cage	1936	1937	1938
IV	217	214	598
V	61	358	743
VI	--	173	685

The possible effects of the feeding which occurred and photographs of this feeding are given in connection with later discussion. The following studies have been made on these caged trees: yearly terminal growth, yearly elongation of ten tagged twigs on each tree, length of needles on ten tagged twigs and terminal, each season, and percent of total twigs on which feeding occurred, by whorls. The summary of these measurements indicates a lessening of twig growth and needle length for the period during which beetles were introduced. This is merely stated as a matter of record since three trees obviously do not constitute a sample. Smaller growth and shorter needles could well be due to climatic factors or even to the effects of the caging itself.

The primary objective of these experiments was to find out if an attack of M. californica could be forced on a living tree. One tree (IV) was felled in the spring of 1939 and examination has shown that it is possible to force such an attack. This is a most important demonstration as opposed to the lack of success in forcing attacks on logs.

Caged Tree IV: Caged Tree IV was felled this past spring and a complete analysis made of the establishment of incipient brood. The population figures for successive feet along the bole are given in Table IX. A discussion of "pits" has been given previously. Figure 17 shows these "pits" and incipient galleries on a portion of the bole of this tree. The large number of these pits would indicate that the establishment of the newly hatched larvae in the region of the cambium may be an extremely vulnerable point in the life cycle. A few of the galleries were examined to determine the age of the larvae. In five cases out of ten the larvae were two years old, having developed from eggs laid during the 1937 season. Figures 18 and 19 show the detail of a successful larval mine in this tree.

In addition to the introduction of beetles, 301 viable eggs were placed on the bole of the tree between the heights of three and seven feet. Table X indicates that this method of forcing an attack may have been partially successful as larvae were established in this region of the bole.

Table IX

DISTRIBUTION OF M. CALIFORNICA ATTACK ON CAGE TREE IV.

Height on Bole in feet	Pits	Incipient galleries	
		Successful	Unsuccessful
0-1	22		2
1-2	70		
2-3	89		
3-4	78	5	
4-5	56	28	14
5-6	76	19	8
6-7	77	2	-
7-8	63	1	1
8-9	85	2	-
9-10	100	4	1
10-11	80	-	1
11-12	60	1	-
12-13	57	10	5
13-14	39	10	3
14-15	49	2	1
15-16	39	2	5
16-17		1	1
17-18			3
Total 0-18	1,040	87	45

In making a detailed analysis of growth for the caged tree, a check tree of similar size and age was selected. The following facts were established in this comparison:

1. In both trees the terminal growth was less in 1938 than in 1937. In the check tree, however, the 1937 growth was distinctly greater than that of 1936, while in the caged tree the 1937 growth was less than that of 1936.

2. The measurement of lateral twig growth was separated above and below the 1930 whorl, with the belief that the figures for the top portion of the tree would possibly be more significant. Below the 1930 whorl the lateral twig growth dropped off in both trees during the period 1936-1938. Above, in the check tree, the 1937 growth was practically the same as that of 1936, while the 1938 growth was considerably greater. In the caged tree the 1937 growth was less than that of 1936 and the 1938 growth practically the same as the 1937.

3. The needle complement (number of needle bundles) increased from 1936 to 1938 for both trees, above the 1930 whorl. Below the whorl the complement increased in the check tree, but dropped in 1938 in the caged tree.

4. Needle length increased during the period 1936-1938 for both trees, both above and below the 1930 growth whorl.

From these facts no definite conclusions can be drawn as to any effect of incipient attacks on the caged tree. The figures are presented largely as a matter of record for comparison in future studies. From the writer's conception of the flathead role, it is not to be expected that a few incipients would necessarily produce any outstanding effect on the host tree within a brief period.

Logs

The results of forced attack studies have already been mentioned, and are summarized in Table X for M. californica, and in Table XI for M. gentilis. Cages used in forced attack studies were those described under Facilities. Beetles from rearing container emergence were introduced to the cages at daily or frequent intervals. In 1937 a few field collected adults were used in forcing experiments. Foliage for adult feeding was provided with the exception of Cage F and G in 1937. Logs were cut from a green tree which was examined to determine that no incipient broods were present. The average log was three and one-half feet in length and 12 to 18 inches in diameter. Logs were disposed both vertically and horizontally, with and without paraffined end, and with or without one end in water. It was apparent that horizontally disposed logs were more attractive to the beetles. Of the total eggs deposited in any cage, a very small percentage was found on the logs. The poles, 3 to 6 inches in diameter and 5 to 6

Table X
FORCED ATTACK STUDIES - MELANOPHILA CALIFORNICA
Record of Cages, 1937

Cage	Log or Pole No.	Period of Exposure	Position	No. of Beetles Present	Examination		
					Date	Sample area (sq. in.)	What was found
D	FH 37-32 (1)	21 days	Prone	392	8/6/37	151	No infestation
					8/27/37	16	No infestation
					10/1/37	96	No infestation, contaminated, no emergence in 1938.
D	FH 37-33 (1)	21 days	Prone	392	8/6/37	142	No infestation
					8/27/37	16	No infestation
					10/1/37	96	No infestation, no emergence 1938
D	FH 37-36 (3)	12 days	Prone	45	8/27/37	32	No infestation
					10/1/37	224	No infestation, no emergence 1938
D	FH 37-36 (5)	12 days	Prone	45	8/27/37	25	No infestation
					10/1/37	312	No infestation, contamination, no emergence in 1938
D	Pole D		Upright		8/13/37	18	No infestation, no emergence 1938
					9/3/37	24	No infestation, no emergence 1938
D	Pole D2		Upright		8/13/37	18	4 incipients, no emergence in 1938
D	Pole D3		Upright		8/13/37	21	5 incipients, 1 dead
					9/3/37	16	3 incipient galleries, 1 small larva, no emergence in 1938
D	Pole D4	21 days	Upright		9/3/37	16	1 small larva, 2 successful incipient galleries
					11/24/37	18	No brood, no emergence in 1938
E	FH 37-33 (2)	30 days	Prone	16	8/27/37	48	No infestation
					10/1/37	224	No infestation
					11/30/37	64	No infestation
					5/17/38	102	No infestation, no emergence 1938
E	FH 37-32 (2)	30 days	Prone	16	8/27/37	32	No infestation
					10/1/37	32	No infestation, contaminated, no emergence in 1938

Record of Cages, 1937 (continued)

E	Pole E		Upright		8/13/37 5/19/38	27 48	6 larvae, growing 2 galleries, 1 growing larva, no emergence in 1938
E	Pole E2		Upright		8/13/37 9/3/37	18 18	9 incipients, 2 growing larvae 2 small, 1 large larvae, no emergence in 1938
E	Pole E3	22 days	Upright	9	9/3/37	18	3 small larvae, 1 gallery, no emergence in 1938
*F	FH 37-32 (3)	27 days	Prone	115	8/4/37	All surface	No infestation, no emergence 1938
*F	FH 37-33 (3)	27 days	Prone	115	8/4/37	All surface	No infestation, no emergence 1938

* No foliage provided for adult feeding.

Table X (continued)

Record of Cages, 1938

Cage	Log or Pole No.	Period of Exposure	Position	No. of Beetles Present	Examination		
					Date	Sample area (sq. in.)	What was found
C	Log E 2(1)	27 days	Prone	585	10/20-21/38	209	No infestation
					5/5/39	59	2 incipients (1 dead), BH contamination
C	Log E 2(4)	94 days	Upright	678	10/20-21/38		No infestation
C	Log E 3(2)	67 days	Prone	183	10/20-21/38	206	14 small larvae in phloem
					5/5/39	180	Several small galleries, no brood
C	Pole (C-1)	9 days	Upright	260	April, 1939		No infestation
C	Pole (C-2)	3 days	"	201	" "		" "
C	Pole (C-3)	4 days	"	178	" "		" "
C	Pole (C-4)	59 days	"	159	" "		" "
C	Pole (C-5)	4 days	"	152	" "		" "
C	Pole (C-6)	7 days	"	112	" "		" "
C	Pole (C-7)	7 days	"	69	" "		" "
C	Pole (C-8)	7 days	"	62	" "		" "
C	Pole (C-9)	14 days	"	45	" "		" "
C	Pole (C-10)	9 days	"	12	" "		" "
D	Log E 2(2)	27 days	Prone	23	10/20-21/38	328	2 small larvae in phloem
					5/5/39	432	No infestation
D	Log E 2(5)	94 days	Upright	87	10/20-21/38	168	No infestation
D	Log E 3(1)	67 days	Prone	74	10/20-21/38	468	14 small larvae in phloem
					5/5/39	60	A few galleries, no infestation
D	Pole (D-1)	9 days	Upright	11	April, 1939		No infestation
D	Pole (D-2)	4 days	"	95	" "		" "
D	Pole (D-3)	2 days	"	73	" "		" "
D	Pole (D-4)	8 days	"	55	" "		" "
D	Pole (D-5)	10 days	"	40	" "		" "
D	Pole (D-6)	21 days	"	17	" "		" "
D	Pole (D-7)	17 days	"	3	" "		" "

Record of Cages, 1938 (continued)

G	Log E 1(1)	38 days	Prone	254	10/20-21/38	238	No infestation
G	Log E 1(2)	105 days	Upright	254	10/20-21/38	223	No infestation
G	Log E 3(3)	67 days	Prone	124	10/20-21/38	194	13 small larvae in phloem
					5/5/39	128	1 gallery, no infestation
G	Pole (G-1)	9 days	Upright	150	April, 1939		No infestation
G	Pole (G-2)	2 days	"	132	" "		" "
G	Pole (G-3)	5 days	"	99	" "		" "
G	Pole (G-4)	8 days	"	73	" "		" "
G	Pole (G-5)	17 days	"	39	" "		" "
G	Pole (G-6)	14 days	"	14	" "		" "
G	Pole (G-7)	17 days	"	6	" "		" "

Table XI

FORCED ATTACK STUDIES - MELANOPHILA GENTILIS
Record of Cages, 1937

Cage	Log or Pole No.	Period of Exposure	Position	No. of beetles present	Examination		
					Date	Sample area (sq. in.)	What was found
C	FH 37-26 (3)	17 days	Prone	91	8/6/37	153	2 galleries
					8/27/37	32	Nothing found
C	FH 37-28 (3)	13 days	Prone	91	8/6/37	127	1 larva, 16 galleries
					8/27/37	32	Nothing found
					10/1/37	48	2 larvae
					10/30/37	64	1 larva and contamination
					5/17/38	--	Few galleries, no larvae
C	FH 37-35 (2)	26 days	Prone	33	8/6/37	238	5 galleries, 2 larvae
					8/27/37	16	3 larvae
					10/1/37	16	2 larvae
C	FH 37-35 (3)	26 days	Prone	33	8/6/37	94	Nothing found
					8/27/37	32	Nothing found
					10/1/37	212	Nothing found
					5/17/38	97	Nothing found
C	FH 37-36 (1)	13 days	Prone	6	8/27/37	32	Nothing found
					10/1/37	224	Nothing found
C	FH 37-36 (6)	13 days	Prone	6	8/27/37	32	Nothing found
					10/1/37	412	Nothing found
C	Pole C	13 days	Upright	91	8/13/37	30	10 larvae, 2 galleries
					9/3/37	27	5 large larvae
C	Pole C-2	8 days	Upright	37	8/13/37	24	11 larvae, 2 galleries
					9/3/37	20	1 small, 2 large larvae (one dead) 1 gallery
C	Pole C-3	10 days	Upright	22	8/13/37	24	4 larvae, 1 gallery
					9/3/37	22	4 larvae
					11/24/37	21	5 larvae
C	Pole C-4	22 days	Upright	12	9/3/37	16	2 larvae
C	All Poles						Rearing 1938 - C Poles yielded 19 M.g. adults

Record of Cages, 1937 (continued)

G	FH 37-36 (2)	17 days	Prone	148			Nothing found, discarded. (No foliage in cage)
G	FH 37-28 (2)	13 days	Prone	89			Nothing found, discarded. (No foliage in cage)
H	FH 37-26 (1)	17 days	Prone	97	8/6/37	148	Nothing found
					8/27/37	32	Nothing found
					10/1/37	128	Contaminated
H	FH 37-28 (1)	13 days	Prone	82	8/6/37	130	1 dead larva
					8/27/37	26	Nothing found
					10/1/37	All bark	Contaminated
H	FH 37-35 (1)	26 days	Prone	104	8/6/37	60	1 larva
					8/27/37	16	2 larvae (1 dead)
					10/1/37	48	5 larvae
					11/30/37	48	2 larvae
					5/17/38	86	Few galleries, no brood
H	Pole H		Upright		8/13/37	20	Contamination
					9/3/37	24	Nothing found
H	Pole H-2		Upright		8/13/37	17	2 larvae
					9/3/37	21	2 larvae
H	Pole H-3	10 days	Upright	48	8/13/37	20	8 larvae
					9/3/37	21	1 larva, 1 gallery
H	Pole H-4	20 days	Upright	33	9/3/37	16	Nothing found
					11/24/37	24	2 larvae (1 dead)
H	All Poles					No rearing in 1938	

Table XI (continued)

Record of Cages, 1938

Cage	Log or Pole No.	Period of Exposure	Position	No. of Beetles Present	Examination		
					Date	Sample area (sq. ft.)	What was found
E	Log E 2(3)	94 days	Prone	49	10/20-21/38	1.5	10 galleries, no larvae found
					5/5/39	1.26	Several very small galleries, no brood.
E	Log E 2(6)	94 days	Upright	49	10/20-21/38	1.35	Nothing found
E	Pole E-1	9 days	Upright	18			Used for egg studies
	Pole E-2	7 days	"	11			" " " "
	Pole E-3	8 days	"	10			" " " "
	Pole E-4	48 days	"	4			" " " "
F	Log E 1(5)	103 days	Upright	115±	10/20-21/38	1.4	1 larva
					5/5/39	.195	1 prepupa, several galleries. 2 M.g. emerged, July 4, 1939
F	Log E 1(6)	103 days	Prone	115±	10/20-21/38	1.33	Galleries, no brood
					5/5/39	1.75	Few galleries, contamination
F	Pole F-1	9 days	Upright	61			Used for eggs
	Pole F-2	7 days	"	22			" " "
	Pole F-3	8 days	"	18			" " "
	Pole F-4	48 days	"	14			" " "
H	Log E 1(3)	38 days	Prone	297	10/20-21/38	1.5	7 larvae
					5/5/39	.78	Nothing found
H	Log E 1(4)	142 days	Upright	436	10/20-21/38	1.5	Nothing found
H	Log E 3(5)	104 days	Prone	205	10/20-21/38	1.25	Nothing found
H	Pole H-1	9 days	Upright	186			Used for egg studies
	Pole H-2	7 days	"	161			" " " "
	Pole H-3	4 days	"	154			" " " "
	Pole H-4	7 days	"	123			" " " "
	Pole H-5	7 days	"	103			" " " "
	Pole H-6	7 days	"	81			" " " "
	Pole H-7	14 days	"	68			" " " "
	Pole H-8		"	39			" " " "

feet in height which were supplied in connection with the foliage were favored for oviposition. Possibly such material was too small in size. However, gentilis was reared from poles, and in the field californica can develop in branches down to a small diameter.

In 1934, 10 logs were exposed to adults of M. californica. No foliage was supplied. In no case was any brood found in 1935.

In addition to forcing attacks by placing logs in cages with adults, an attempt was made to establish broods by placing viable eggs and newly hatched larvae on logs. On one log 37 viable eggs of M. californica were placed; on two other logs 31 and 93 newly hatched larvae of the same species were placed. In no case was any brood found an examination of the logs two months later.

Although the amount of material is small, it is believed that, taken with other evidence, there is sufficient reason to believe that californica broods cannot develop from eggs in dead host material.

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SECTION VI

NOTES ON HABITS

FAST GROWING LARVAL STAGE

The initiation of the fast growing larval stage is a little understood point in the life cycle. It is probably associated with some physiological change in the host at time of death. It can be initiated by felling a living tree, and by windfall. In standing trees it can be initiated by the attack of other species of insects, although in most cases the stage has already been entered into by flathead broods before such attacks occur.

ADULT

Feeding

During the 1936 season it was first demonstrated that feeding on the needles of pine was a requisite of successful adult life. When beetles, of either species, were placed in a cage on a tree bole, or in other cages without foliage, there was practically no activity and their life was limited to a very few days. When beetles were placed in tree cages or foliage was introduced to the smaller cages, feeding was very extensive. An example of adult feeding is shown in Figure 13.

Feeding occurred in all cases in six portable cages, three tree cages and in laboratory jars during four seasons of study. It occurred when other activities, such as copulation, flight or oviposition were inhibited, and apparently some feeding occurred during the night hours.

Possible Effects of Adult Feeding: The considerable amount of adult feeding has already been mentioned. In the caged tree studies the loss of needles as a result of feeding injury was very evident. The best comparative photographs are of Caged Tree VI, to which beetles were introduced only in 1937 and 1938. Figure 14 shows the tree in the late summer of 1936 and Figure 16 shows the same tree in the spring of 1939. The difference in density of needle complement is entirely due to feeding of M. californica.

In feeding adults indicate a choice of the needles of the current year, although needles of the entire complement may be fed upon. Table XII gives the percent of twigs injured, by needle complements, for three concentrations of M. californica populations in 6 foot cages.

Table XII

EXAMPLE OF EXTENT OF FEEDING OF MELANOPHILA CALIFORNICA
(On foliage supplied for 6-foot cages)

Cage	Percent of twigs injured according to year of needle complement where injury occurs						No. of Beetles per Twig
	1933	1934	1935	1936	1937	1938	
C	50	25	50	60	100	100	5.70
D	17.3	66.7	53.8	92.9	84.2	90.5	.33
G	38.5	46.7	65	79.2	84	100	2.75

Table XIII presents similar data for the three tree cages for the feeding of the 1937 season, with less intense feeding probably due to the lighter populations.

Table XIII

PERCENT OF TWIGS INJURED BY FEEDING

Tree	Percent of twigs injured according to year of needle complement where injury occurs						No. of Beetles per Twig
	1932	1933	1934	1935	1936	1937	
IV	16	22	20	22	52	48	.47
V	0	0	7	15	54	59	1.10
VI	0	3	4	10	22	53	.62

In 1938, 181 twigs from 8 felled, high risk trees were examined for evidences of feeding. The twigs were selected at random along the bole of the felled trees. In six trees there had been feeding on all the twigs collected. On a seventh tree, needles on 95 percent of the twigs had been injured, and on the eighth tree, needles on 54 percent of the twigs had been fed upon. It is, of course, impossible to say that all the feeding was caused by Melanophila adults, since their type of feeding is characteristic of Buprestids in general. However, from the fact that adults of Melanophila species were observed feeding on the foliage after the trees were felled, it is probable that a good proportion of the injury was due to those species. On these trees it was also noted that the heaviest feeding occurred on the current needle growth. The lightest feeding seemed to occur on the tree which had the poorest needles - with respect to color, length and density.

From observations on foliage in small cages, caged trees, and trees in the field, it is believed that the adult feeding could, under some circumstances, be an important factor. At times the needle complement might be sufficiently reduced to seriously affect the transpiration

power of the tree as a whole. This is by no means implied to be of common and general occurrence, but is mentioned as another factor which may enter the picture of the role of M. californica.

Tropisms

When adults emerge from bark in rearing containers, they evidence a definite phototropic response. Exposure of beetles in small laboratory cages to artificial and natural light, however, failed to elicit any phototropic response. When such cages were placed near a stove, even at night, the beetles immediately became active. Approximately 70° F. was the temperature necessary to stimulate any activity, other conditions being favorable.

Flight

In the six-foot portable cages it has been noted that in all cases the beetles are quiescent during the cool, morning hours, and only become active during the warmer hours of the day. Any disturbance in the cage when the temperature is high causes the beetles to fly about "nervously". A similar disturbance in the cool morning hours results in the beetles dropping to the floor of the cage and making no effort to fly. Considerable sporadic flying has been observed in the field and in cages intermittent with copulation, feeding and oviposition.

Sex Ratio

Sex determinations have been made on 479 individuals of M. californica and 178 of M. gentilis which were collected after death in cages. Additional determinations were made on 314 adults of californica and 149 of gentilis which were found in rearing containers at the end of the 1938 season. For californica the sex ratio was .503 and .478 respectively for the two sets of determinations. For gentilis the ratio was .36 for cage beetles and .523 for rearing container adults. In all probability the ratio is approximately .5 for both species.

Copulation

Approximately 100 cases of copulation of M. californica and M. gentilis have been observed under caged conditions. A few cases have been observed in the field. Copulation has never been observed in cages where foliage was not present. Hence, it has been concluded that feeding is necessary for sexual maturity.

Length of Adult Life

Studies on the length of adult life have of necessity been confined to cages. During the 1936 season approximately four days was the average length of life of beetles of both species. It is now known that unsatisfactory cage conditions probably contributed largely to this brevity. In one tree cage a length of life of at least 15 days was recorded for one beetle (M. californica). During 1937 more favorable cage conditions were provided. For 36 field collected adults of californica, placed in a six foot cage, the average length of life was 19.5 days, with a maximum of 41 days. These figures are of course minimum since there is no way of knowing the age of the beetles when they were collected. For 91 field collected adults of M. gentilis the average length of life was 16.8 days and the maximum 43, again minimum figures. For several hundred reared adults of californica the average length of life was approximately one week.

During the 1938 season more detailed records were kept of the length of life of reared adults in portable cages. Daily introductions and counts of the number of live beetles were made, thus it was possible to figure a minimum age. For 344 M. californica adults this minimum age averaged 13 days, and a maximum of 51 days was recorded. The distribution of length of adult life is given in Graph 3. For 208 adults of M. gentilis the average was 19 days, with a maximum of 81 days. The distribution is given in Graph 4. No difference in length of life of male and female has been found.

During the present (1939) season a few reared adults of M. californica have been placed in small laboratory jars for observation. One beetle lived 62 days in confinement.

Development of Ovaries

As indicated previously, cage observations have apparently shown that feeding is necessary for sexual maturity. Some 73 adults of M. californica have been dissected for a study of ovary development. The observations are given in Table XIV. At least 10 days are required for the eggs to differentiate sufficiently to enable accurate counts. The largest number of eggs counted was 242. Considerably more dissection would be necessary to determine the egg potential of the species. No females of M. gentilis have been dissected.

Oviposition

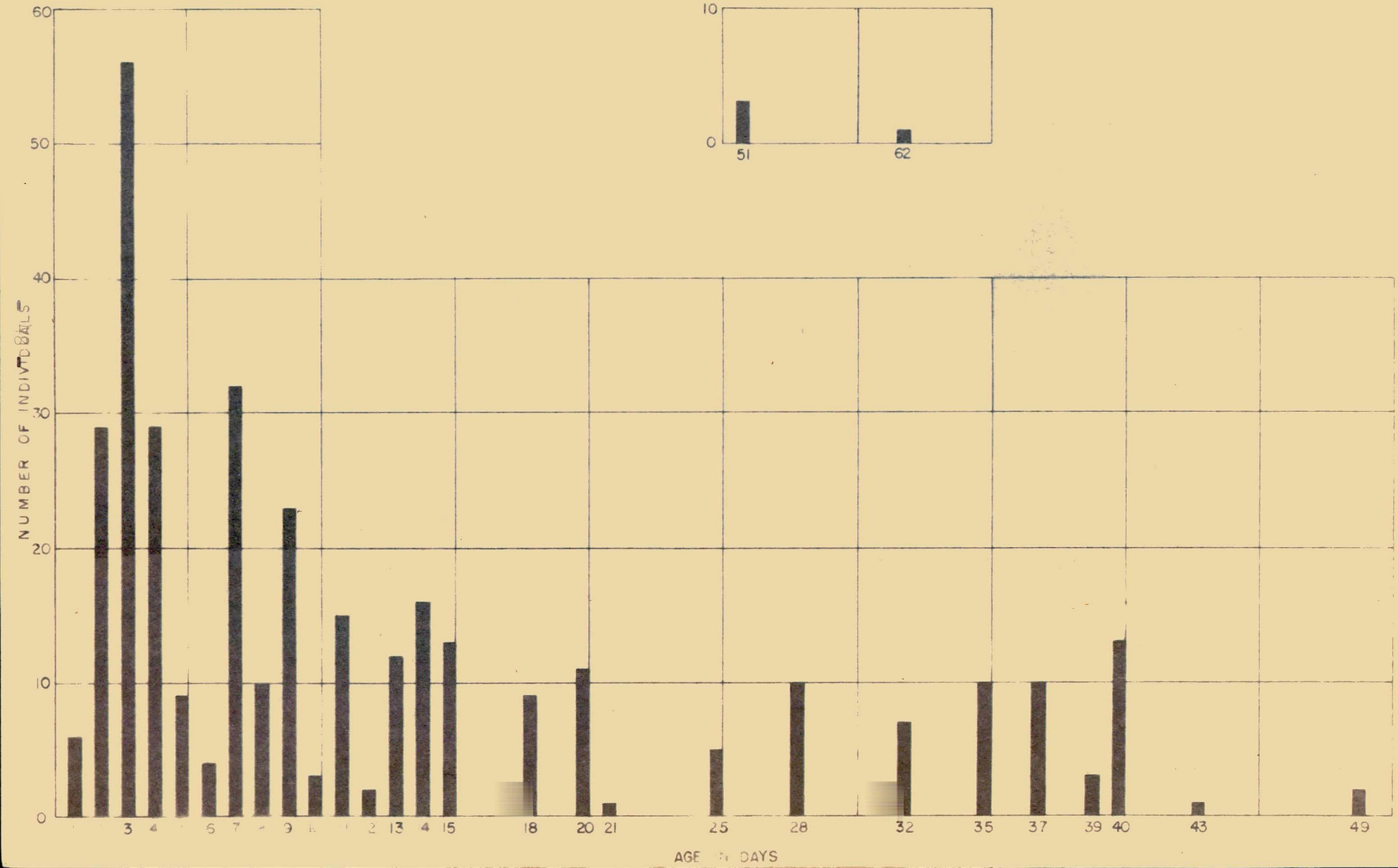
Oviposition has been observed with both species in the field and under cage conditions. Adults crawl about in bark crevices apparently selecting a suitable place for oviposition. Eggs are placed between bark scales bordering on a crevice. When the ovipositer, which is extended fully two-thirds the length of the abdomen, is not hidden from view, eggs can be seen passing down the oviduct.

XXXXXX

MINIMUM LENGTH OF ADULT LIFE — MELANOPHILA CALIFORNICA
1938

GRAPH 3

PORTABLE CAGE C



MINIMUM LENGTH OF LIFE OF MELANOPHILA GENTILIS — 1938

(208 INDIVIDUALS TOTAL)

(PORTABLE CAGE H)

GRAPH 4

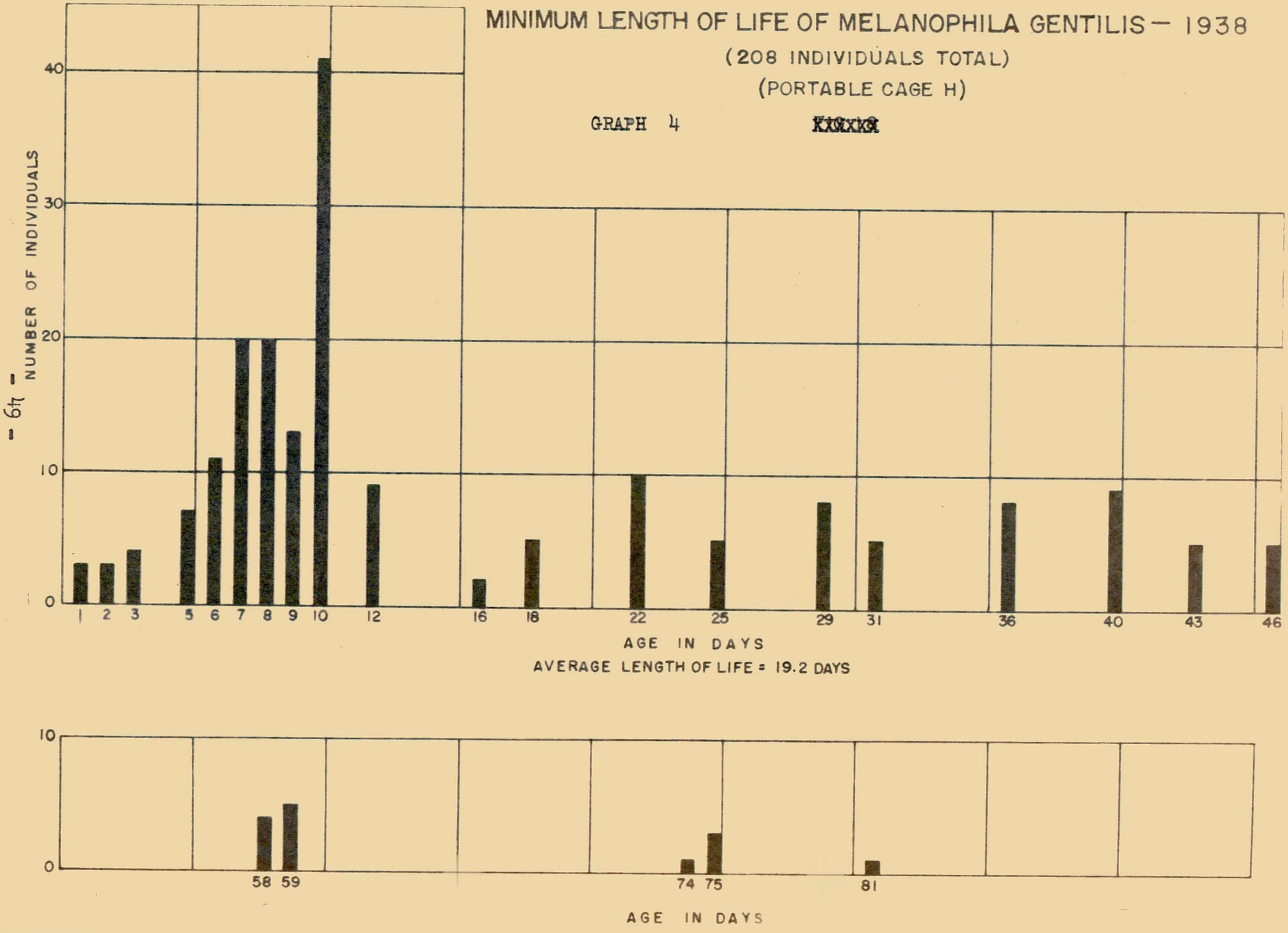


Table XIV

DETERMINATION OF THE PREOVIPOSITION PERIOD AND THE REPRODUCTIVE POTENTIAL OF MELANOPHILA CALIFORNICA
VALUES OBTAINED BY DISSECTING ADULT FEMALES OF VARIOUS AGES
Record of Cases

Age in Days	Total eggs	No. large eggs	Total eggs	No. large eggs	Total eggs	No. large eggs	Total eggs	No. large eggs	Total eggs	No. large eggs	Total eggs	No. large eggs	Total eggs	No. large eggs	Total eggs	No. large eggs	Total eggs	No. large eggs
1	*		0		0		0		0		0		0		0			
2	48*		*		0		0		0									
3	28*		147*		0													
4	*																	
5	72*		72*															
6	72*		*		*		*		*									
7	*		*		*		*		*		*		*		*		*	
8	72*		72*		*		*											
9	*		*		*													
10	*																	
11	120	24	*		126	69	72											
12	190	33	115	43	177	73												
13	182	62	165	65	116	45	45	26	7		86	46	*		*			
10-16	108	38	115	29	105	35	153	51	111	9	94	28						
14																		
15	117	61																
16	93	22																
17																		
18																		
19																		
20																		
21																		
22																		
23																		
24	79	22																
25	221	77	242	77	106	31	32	12	101	43								
26	169	137	148	78	152	39												

* Eggs starting to differentiate, but not possible to count in some cases.

EGG STAGE

Occurrence of Eggs in Groups

The deposition of eggs of M. californica in groups is given in Table XV. These figures are based on 849 eggs collected from one cage during the 1938 season. 34.3 percent of the eggs occurred in groups of two. The largest group of eggs was 13 in number.

Table XV

EGGS OF MELANOPHILA CALIFORNICA - OVIPOSITION GROUPS
(Based on 849 eggs collected in cages)

	Number of eggs per group												
	1	2	3	4	5	6	7	8	9	10	11	12	13
No.of eggs in groups	291	258	105	64	55	18	21	24					13
No. of groups	291	129	35	16	11	3	3	3					1
% of eggs in groups	34.3	30.4	12.4	7.5	6.5	2.1	2.5	2.8					1.5

Viability

The percent viability was determined on a total of 1597 eggs of M. californica which were taken from poles placed in portable cages. Table XVI indicates 42.2 percent viability for eggs which were collected immediately following deposition, 43.8 percent for eggs which were collected during the period of incubation, and 57.8 percent for eggs which were examined after the period of incubation. The separation is made because of the possibility that viability might have been influenced by handling the eggs in rearing work. For all the eggs taken together the viability was 50.8 percent.

For gentilis the viability was determined on 367 eggs. Table XVII indicates 33.6 percent viability for eggs collected immediately after deposition, 40.3 percent for eggs collected during the incubation period, and 24.4 percent for eggs examined after the period of incubation, with a 32.7 percent viability for all eggs taken together.

Table XVI

MELANOPHILA CALIFORNICA - EGG VIABILITY. 1938

Eggs collected immediately after oviposition

Cage	Total No. of Eggs	Number of eggs viable	% Viability	Number of Parasites	% Parasitism of total eggs
C	91	41	34.1	1	1.1
D	12	4	33.3		
F	5	2	40.0		
G	311	140	45.0	1	.3
Total	419	177		2	
Average			42.2		.5

Eggs collected during period of incubation.

Pole					
C-2	14	7	50.0		
C-3	147	77	52.4	8	5.4
G-2	78	14	17.9	4	5.1
G-3	76	33	43.4	3	3.9
G-4	14	13	86.7		
Total	329	144		15	
Average			43.8		4.6

Counts made after incubation period.

Pole					
C-4	238	180	75.6	18	7.6
C-5	85	38	44.0	2	2.4
C-6	143	129	90.2		
C-7	155	54	34.8		
C-8	50	14	28.0		
C-9	13	9	69.7		
D-4	103	33	32.0		
D-5	41	23	56.1		
D-6	11	3	27.3		
G-5	10	8	80.0		
Total	849	491		20	
Average			57.8		2.4

Table XVII

MELANOPHILA GENTILIS - EGG VIABILITY
1938

Eggs collected immediately after oviposition

Cage	Total No. of Eggs	Number of eggs viable	% Viability	Number of Parasites	% Parasitism of total eggs
E	82	22	26.8		
F	14	4	28.6		
H	127	49	38.6	2	1.6
Total	223	75		2	
Average			33.6		0.9

Eggs collected during period of incubation

Pole					
H-3	60	24	40.0		
E-3	1	1	100.0		
H-4	1			1	100.0
Total	62	25		1	
Average			40.3		1.6

Counts made after period of incubation

Pole					
H-4	10	3	30.0	1	10.0
H-7	72	17	23.6	8	11.1
Total	82	20		9	
Average			24.4		10.9

POPULATIONS

Incipient Populations

An initial sample count of population was made for all logs which were cut from living trees and brought to the laboratory for rearing purposes. During 1936 and 1937 a total of 40.16 square feet, representing 56 logs from 16 trees (Table IV) showed an average incipient population of 17.26 larvae to the square foot. It must be borne in mind that these trees were chosen for rearing studies since they did contain heavy broods of incipient larvae. The extremes of population ranged from 0 to 41.67 larvae per square foot. In 47 logs from 14 of the same trees there was also found an average of 12.35 unsuccessful incipient galleries per square foot, ranging from 0 to 29.63. It is of interest to note that logs from the tree with the highest population of living incipient larvae had the second highest population of unsuccessful incipients, 25 per square foot.

Additional population figures were secured from sample counts on the 19 living trees which have been sampled periodically since 1936. These samples, presented in Table V in connection with the discussion of the quantitative factor in incipient infestations showed an average of 9.52 incipient larvae per square foot.

Prepupal

For 520 square feet of bark from standing trees in 1938, the average prepupal population was 517 per square foot. For 130 square feet of windfall material the average was 6.9, for 38 square feet from host trees felled in the fall of 1937, 5.4 per square foot and for 55 square feet from logs in rearing, 5.0. These figures should be compared with emergence figures of 4.22, 6.02, 4.92 and 3.96 beetles per square foot. With the exception of logs, both species are included since the broods cannot be separated in the prepupal stage. However, gentilis composed only 2.1 percent of the emergence in standing tree material and 5 percent for the felled material.

Adults

In the course of rearing adults a large number of lots of bark, totaling more than 2000 square feet, have been used. Table XVIII gives the emergence, in terms of beetles per square foot of bark, from the various types of host material for the three seasons prior to 1939. Standing trees, slash and windfalls furnish the greater proportion of the host material for M. californica in any one season. (It must be remembered that in all cases the californica brood starts out in the standing tree.)

Table XVIII

SUMMARY OF 1936, 1937 and 1938 FLATHEAD EMERGENCE

Source of Bark	Year	Quantity of Bark (sq.ft.)	Emergence per sq. ft.			Notes
			M.californica	M.gentilis	Total	
Standing trees	1936	512	2.61		2.61	
" "	1937	128	1.78		1.78	
" "	1938	520	4.13	.09	4.22	
Total or Average		1160	2.84	.03	2.87	
Slash	1937	66	.41	5.17	5.58	Stored outside overwinter
"	1937	136	4.31	.31	4.62	Stored inside overwinter
"	1938	124	5.42	.05	5.47	
Total or Average		326	3.38	1.84	5.22	
Windfall	1937	112	2.94	3.95	6.89	
"	1938	130	2.79	9.25	12.04	
Total or Average		242	2.86	6.60	9.46	
Logs	1937	155	.66	.03	.69	
"	1937	22.5	11.38	.22	11.60	
"	1938	55	3.96		3.96	
Total or Average		232.5	5.33	.08	5.41	
Felled trees on ground overwinter	1938	38	4.89	.03	4.92	
Standing, fire-injured	1937	6	3.0		3.0	

The three year average emergence from these types of material is 2.84, 2.86 and 3.38 respectively. Emergence varied greatly for different lots, even of the same type of host material, and even varied considerably within a single tree bole. The heaviest emergence was 22.6 californica adults per square foot for seven square feet of bark. This material was placed in rearing in 1938 from the top side of a flathead brood tree which had been felled during the summer of 1937.

Slash and windfalls furnish the chief brood material of gentilis. The average emergence per square foot for 1937 and 1938 was 1.84 and 6.60 respectively.

SECTION VII

ENVIRONMENTAL FACTORS

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SECTION VII

ENVIRONMENTAL FACTORS

HOST PREFERENCES

The record of emergence from more than 2000 square feet of bark in rearing during the 1936-1938 seasons is given in Table XVIII previously referred to. A brief discussion is included here of the occurrence of the two species in the several types of host material.

Standing Trees

This is the normal condition of host material for emerging broods of M. californica, composed of trees which had supported incipient populations. In 1936 and 1937 no gentilis adults were reared from this type of material. In 1938 a small amount of gentilis emergence occurred from standing tree bark. During composition studies in 1937 three trees were found in which gentilis was thought to be present on the basis of type of galleries, and rearings supported these determinations. These three trees showed signs of what was interpreted as cold injury, resulting from the abnormally low temperatures. Thus it is believed that cold injury, and possibly other factors, may at times provide a limited amount of suitable host material for the development of M. gentilis in standing trees. On the basis of 1160 square feet of bark reared out over a period of three years, it can be stated that standing trees are not the normal host material of M. gentilis.

Slash

Slash is material from which both species of Melanophila may emerge in large numbers. Where californica emerges, incipient galleries have always been found in the host material, indicating that the brood was established before the tree was felled. Considerable variation in the amounts of emergence of the two species in different lots of host material would be expected. Factors such as the original incipient population, time of year slash is created in relation to period of gentilis adult activity, and competition with other species would have considerable influence.

During the 1938 season, eight trees containing incipient flathead broods were felled and disposed for slash studies. The amount of material was insufficient to form any definite conclusions. In general, however, the flathead brood had better success on the top side of the slash which was considerably less suitable for competing species other than flathead. Slash collected in the fall of 1936 indicated that relatively high populations of M. californica can emerge from slash. Since

felling incipient brood trees creates suitable conditions for brood development, it is conceivable that large populations of adults might be developed over local areas.

Windfalls

Considerations in regard to slash likewise apply to windfalls. On the basis of 242 feet of bark from windfalls in two areas it would appear that windfalls may in general furnish more suitable material for the development of gentilis broods than does slash. This is possibly due to the fact that in windfalls the whole tree constitutes the host material while in slash the host material is generally the smaller tops of felled trees.

Fire-injured Material

Rearing of M. californica from fire-injured material has been limited to a single lot. Incipient galleries indicated that californica brood had been present previous to the fire. Such material would possibly be suitable for the development of gentilis brood as well.

Logs

All the log material listed in Table XVIII consisted of logs reared at the Laboratory. It will be noted that in 1937 a small amount of gentilis emerged from this material. The emergence was from logs from a single tree. Logs were cut at the time the tree was felled and at two later periods. Table XIX shows that there was no gentilis emergence from logs cut immediately as the tree was felled, but increasing gentilis emergence with increased time the host material was left in the woods is shown.

Table XIX

EMERGENCE OF M. CALIFORNICA AND M. GENTILIS FROM LOGS WITH REFERENCE TO LENGTH OF TIME LOGS REMAINED IN WOODS AS SLASH.

Exposure in Woods After Felling	Square Feet of Bark	Emergence per sq. ft.	
		M. californica	M. gentilis
None	13	.2	
7/11/36-8/8/36	45	4.9	.1
7/11/36-10/15/36	40	4.1	.4

Summary Statement

All records totalling several hundred, point to the fact that californica is associated, during the initial period of its development, with living host material. Gentilis is associated with dead or dying host material throughout its entire period of development.

MORTALITY FACTORS

Parasitism

In 1937 an egg parasite was reared from cage material of both species. Tentative identification by the Division of Insect Identification was made as an Encyrtid of a genus not previously reported as parasitizing eggs of Buprestidae. During 1938 a total of 37 parasitized eggs of M. californica were found. In two cases the Hymenopterous adult was observed ovipositing on an egg of californica immediately after the latter's oviposition. Adults of the parasite were reared in both cases. Of the total of 419 eggs of M. californica which were observed, all were removed immediately after oviposition and the opportunity for parasitism was not necessarily given. For the remaining 1178 eggs a parasitism of 2.9 percent was recorded. Some of the parasites collected during September did not complete development, but remained overwinter in puparia. In these cases the adult parasites emerged during June, 1939, indicating that the species probably overwinters as a pupa. Additional material has been sent to Washington for determination. The parasitism of eggs on separate poles has been recorded in Table XVI.

The parasitism of 24 gentilis eggs is given in conjunction with Table XVII and indicates a total parasitism of 6.5 percent.

Predators

Predation by woodpeckers is a significant factor during the period of prepupal and pupal development. When prepupal brood bark is collected during the spring of the year numerous woodpecker feeding holes are evident, and many of these can be traced to a prepupal larval cell in the bark. During the 1938 season, counts were made to determine the importance of woodpeckers. For 520 square feet of M. californica brood bark from standing trees 22.84 percent of the original prepupal brood had been removed. For felled trees on 38 square feet of bark, this figure was 25 percent. Windfall bark containing brood of both species was collected in the fall of 1937 and in the spring of 1938 from the same trees. For 41 square feet of bark collected in late November, 10.4 percent of the brood had been removed. For 89 square feet of bark collected in the spring, 16 percent of the brood had been removed.

Adults

Unseasonable weather conditions may be responsible for adult inactivity and consequent light incipient broods.

Natural (Climatic and host)

The natural mortality factors which have been discussed in connection with the individual stages can be briefly summed up:

Eggs: Viability is probably a variable factor. Parasitism may possibly be a factor of importance at times.

Incipient Larvae: A high mortality of larvae may occur at the time when the larvae first reach the cambium region. On trees which are infested with incipient flathead broods, small pits in the wood are commonly found. In one caged tree on which attacks had been forced during three seasons these pits were associated with the unsuccessful establishment of newly hatched larvae. In nearly all cases the gallery could be traced from the pit through the phloem, and in several cases the remains of the dead larva was found in the pit. There was some indication that these larvae may have been "pitched-out". As previously discussed, mortality of larvae in the green tree due to "pitching-out" is common.

Fast Growing Larvae: Unseasonable weather may result in curtailed development of the fast growing brood stage and consequent mortality during the winter period.

The Factor of Competition

The factor of competition is an extremely important one as affects the successful development of flathead brood in the fast growing stage. In the case of top-kills, as shown by several hundred composition analyses, flathead broods may develop without competition with other insects. However, when flatheads enter the fast growing stage along the complete bole, competition with other species is of common occurrence, more particularly D.b. in the lower bole and Ips in the top. In many cases, particularly if it enters the fast growing stage concurrently with the attacks of competitive species, the flathead brood is entirely unsuccessful. This may be due to the difference in rate of development of the species. D.b. has from one and one-half to three generations a year (in northern California), and Ips probably has three or more generations In contrast to this the flathead brood required a summer season to develop through the fast growing stage. Before this development is well under way the food may be completely consumed by the competing species.

As mentioned in the writer's 1937 report, several hundred stem analyses from the Modoc and Lassen showed that flathead were concerned in the infestation of about 50 percent of the ponderosa pines and about

76 percent of the Jeffrey pines. These were successful flathead broods beyond the incipient stage of development. The Jeffrey pine beetle has but one generation a year and hence would be less of a competing factor than D.b. in ponderosa pines.

TEMPERATURE STUDIES

In studying the effects of temperature on the species, 50° F. was chosen as the "threshold of development". This is only an approximate figure, satisfactory since the object of these studies was to show the general relationship of brood development to prevailing temperatures. 50° F. was selected since prepupal brood in bark stored in a cellar at that temperature underwent little if any development.

In these studies observations were generally made once every 24 hours. Hence, in calculating the hour-degrees necessary for a stage of development the end point was considered as occurring at one half the temperature accumulation of the last 24 hour period, the range within which the end point may have been reached.

Temperature and Egg Development

During the 1937 season 26 eggs of M. californica were successfully incubated at a constant temperature of 85° F. The average incubation period, in terms of accumulated hour-degrees of temperature above 50° F. was 6077± 447, ranging from 4496± 482 to 6925±449. In terms of days the average was seven.

For 70 eggs of gentilis similarly reared in 1937 the average was 4495± 429, ranging from 1522± 412 to 9360± 436. or 5 plus in terms of days.

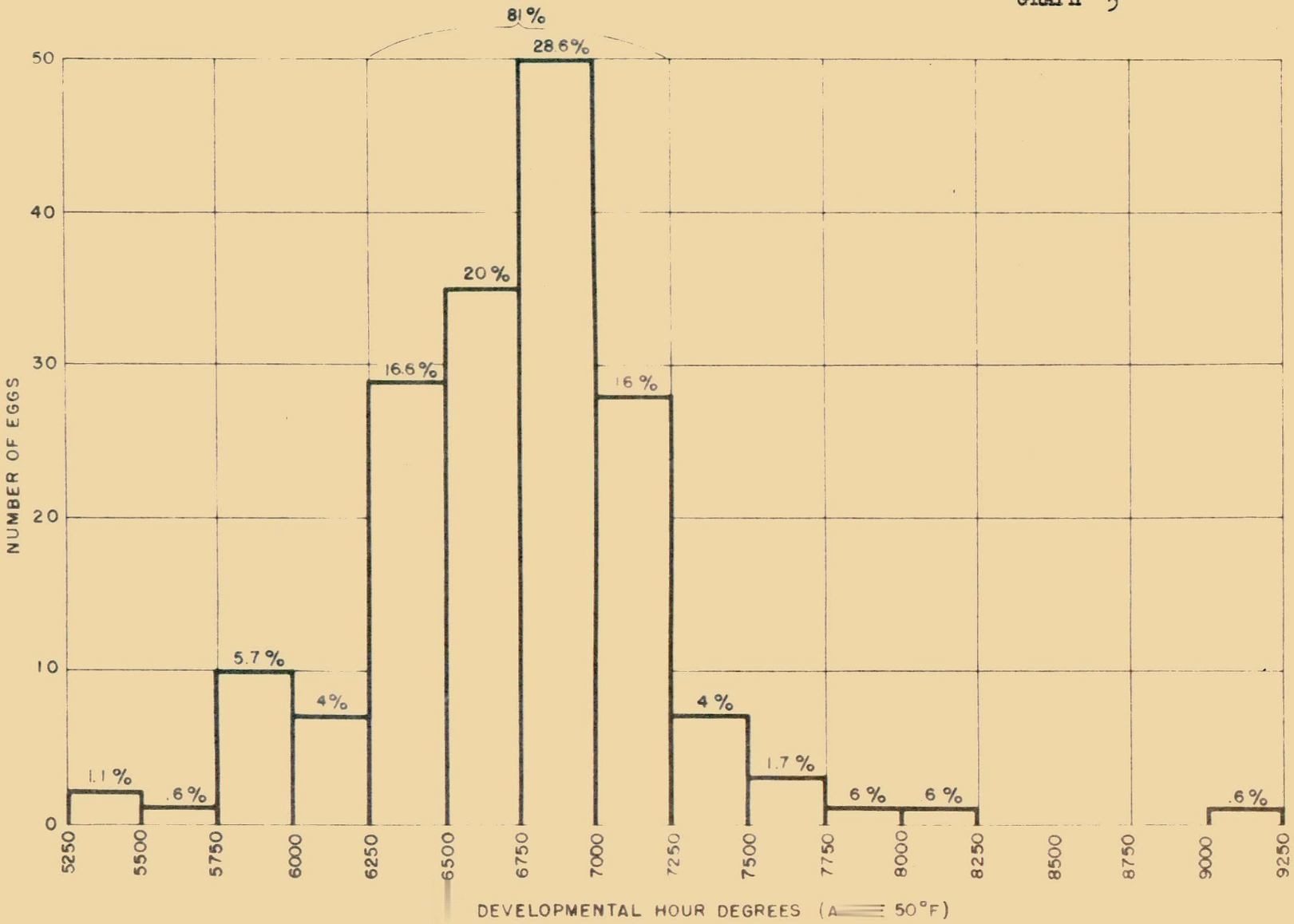
In 1938, 175 eggs of californica were incubated at air temperature. The average period of incubation was 6735± 241 accumulated hour-degrees, ranging from 5226± 292 to 9201± 205. The distribution of incubation period in terms of temperature is given in Graph 5. 81 percent of the eggs incubated within the range of 6250 to 7250 hour-degrees.

For 77 eggs of gentilis reared at air temperature in 1938, the average incubation period was 5709 hour-degrees, ranging from 3755 to 8929.

XXXXXX

MELANOPHILA CALIFORNICA EGGS
PERIOD OF INCUBATION — 1938
(AT AIR TEMPERATURE)

GRAPH 5



Temperature in Relation to Duration of Prepupal Stage

In connection with the previous discussion of the duration of the prepupal stage it was pointed out that subjection of prepupae to room temperature during the fall and winter months did little to hasten pupation.

During January, 1937, a few tests were made of the effect of low temperatures on some 139 prepupae and 20 fast growing larvae. (West, 1937b). The results of these tests are summarized in Table XX. In general, mortality of prepupae ranged from 0 at 0° F. to 25 percent at -14.7° F. One exception was the occurrence of 30 percent mortality on exposure to -7.5° F. Subjection to -15° following an initial exposure to zero temperatures resulted in mortality as high as 50 percent. Fast growing larvae were less resistant, with 20 percent mortality occurring at 0° F. It would be expected that larvae "hardened" in the field would be more resistant than these samples which were taken from logs not exposed to normal winter temperatures. Since to secure a bark temperature of -15° would necessitate considerably lower air temperatures, it is unlikely that significant mortality of prepupae would be of common occurrence in the field. For fast growing larvae mortality from cold may be fairly common. As has been previously stated, larvae of this stage do not overwinter successfully.

During January, 1937, extremely low temperatures were common throughout northern California. At Hackamore a minimum of -34° F. was recorded. Field examination of brood trees over a large area, in April, indicated that there had been very little mortality of prepupal brood. In one tree practically 100 percent mortality was found, but this was decidedly unusual.

In addition to the study of the effect of room temperatures on prepupae, 50 individuals of this stage were used in a study of the effect of moderately low temperatures on the prepupal diapause. The results of this study are presented in Table XXI. These tests indicate that while moderately low temperatures are not necessarily requisite for pupation, the length of the prepupal diapause is definitely shortened by exposure to such temperatures. Brood so treated showed a lower mortality than brood exposed to constant room temperatures. These results also tend to indicate that a period of "warming-up" is necessary prior to pupation.

Temperature in Relation to Pupation

During the spring of 1937, 37 pupae of M. californica were successfully reared to the adult stage at constant temperature. There was an average "warming-up" period (accumulation of effective temperatures) of 6688 hour-degrees before pupation. The maximum accumulation prior to pupation was about 20,000 hour-degrees. At a constant temperature of 85° an average of 7522 ± 854 hour-degrees (9±1 days) was required

Table XX

LOW TEMPERATURE TESTS WITH MELANOPHILA LARVAE

	Test No.		Temp. °F.	Exposure	At end of exposure	Observations - number of larvae alive						% Mortality
						0-12 hrs.	12-24 hrs.	24-48 hrs.	48-72 hrs.	72-96 hrs.	156 hrs.	
	2	10 pp	70	check	all active							0
	x	9 pp	70	check	all active							0
	3	10 pp	0	2 hr.10 min	none frozen	10						0
	5	13 pp	0	2 hr.10 min	none frozen	13						0
I	10	20 pp	-4.8	2 hr.10 min	none frozen		16		16			*5.9
	9	20 pp	-7.5	2 hr.10 min	8 frozen		12		14			30.
	8	20 pp	-10.1	2 hr.10 min	5 frozen	16		18		18		10.
	7	20 pp	-12.5	2 hr.10 min	17 frozen	0	4	12		16		20.
	6	20 pp	-14.7	2 hr.10 min	all frozen	0.2	2	5		15		25.
II	7	10 pp	-15.	2 hr.15 min	all frozen	0		0	3		5	50.
	5	13 pp	-15.	2 hr.15 min	all frozen	0		0	6		8	38.4
III	1	10 lar	70	check	all active	10		9	7			30.
	4	10 lar	0	2 hr.10 min	none frozen	8				8		20.
IV	4	8 lar	-15	2 hr.15 min	all frozen	0		0	6		8	62.5

* 3 prepupal larvae which were injured in some manner have been excluded from calculation of the percent mortality for this test.

pp - prepupae

lar - larvae

Table XXI
DEVELOPMENT OF PREPUPAL LARVAE OF M. CALIFORNICA SUBJECTED TO MODERATELY LOW TEMPERATURES

Lot No.	A			B			C			D			E			F			G			H			I			J		
Date	PP	P	A	PP	P	A	PP	P	A	PP	P	A	PP	P	A	PP	P	A	PP	P	A	PP	P	A	PP	P	A	PP	P	A
Nov.28	5(45°)			5(45°)			5(45°)			5(45°)																				
Nov.30													5(45°)			5(45°)			5(45°)			5(45°)			5(RmTemp)			5(RmTemp)		
Dec. 3	5(32°)			5(32°)			5(32°)			5(32°)																				
Jan.11							5(RmTemp)			5(RmTemp)			5(RmTemp)			5(RmTemp)														
Jan.29	5			5			4			5			5			5			4			5			4			5		
Feb.17	5			4			3			5			5			5			3			5			4			4		
Feb.27													no change																	
Mar. 6													no change																	
Mar. 8	5			4			3			5			2	3		3	2		3			5			4			4		
Mar.12	5			4			3			5			2	3		1	4		3			5			4			4		
Mar.16	5(RmTemp)			4(RmTemp)			3			3	2		1	4		1	4		3(RmTemp)			5(RmTemp)			4			4		
Mar.19	5			4			3			3	2			4	1	1	4		3			5			4			4		
Mar.22	5			4			2	1		3	2			4	1	1	4		3			5			2			4		
													no change																	
Mar.24	5			4			2	1		3	2			3	2	1	4		3			5			2			4		
Mar.25													no change																	
Mar.26													no change																	
Mar.27	5			4			2	1		3	2			2	3	1	4		3			5			2			4		
Mar.29	5			4			2	1		2	3			2	3	1	4		3			5			2			3	1	
Mar.31	5			4			2	1		1	4			2	3	1	2	2	3			5			2			3	1	
Apr. 3													no change																	
Apr. 5	3	2		4			2	1		1	4				3	1	2	2	3			4	1		2			3	1	
Apr. 6													no change																	
Apr. 7	3	2		4			2	1			3	1		2	3	1	2	2	3			4	1		2			3	1	
Apr. 8													no change																	
Apr.9	3	2		4			2	1			3	1		2	3	1	1	3	2	1		4	1		2			3	1	
Apr.10	1	4		4			2	1			2	2		2	3		2	3	2	1		4	1		2			3	1	
Apr.13	1	4		3	1		2	1			2	2		2	3		2	3	1	2		3	2		2			1	3	
Apr.14	1	4		3	1		2	1			2	2		2	3		2	3	1	2		2	3		2			1	3	
Apr.15	1	4		1	1		1	2		1	2	2			3		2	3	1	2		2	3		2			1	3	
Apr.16		5		1	1		1	2		1	2	2			3		2	3	1	3		2	3		2			1	3	
Apr.17							1	1	1																			1	2	1
Apr.19							1		2											3										
Apr.29			5			1	1		2									3		2	1	2	2	1				1	1	2
May 4																				1	2	2		3						
May 10													no change																	
May 14																								3						
May 18			5			1	1		2			3			3			3				2		3						3

for pupation, ranging from 4355± 889 (6 days) to 11151± 919 (13 days). The distribution of indivudual results is shown in Graph 6.

For 8 individuals of M. gentilis the average duration of pupation was 7519± 857, ranging from 7000± 835 to 8593± 748 hour-degrees.

Temperature in Relation to Emergence

Over a period of six seasons, 1934 to 1939 inclusive, emergence records have been collected on Melanophila species. It has been shown that daily emergence correlates fairly closely with daily maximum temperatures and that little emergence takes place below a daily maximum of 70° F. An example of this correlation for M. californica is given in Figure 26. M. gentilis emergence follows the same trend, but tends to occur somewhat earlier each season.

In Figure 27 emergence is expressed in relation to seasonal accumulation of effective temperatures for the seasons 1934-1937. 1938 and 1939 data follow the same trend with the exception that the peak of emergence has a wider range. In both 1938 and 1939 there was a period of unseasonably cool weather during the first week of July which it is believed considerably influenced emergence. It is of interest to note that for the 1937 studies the greatest theoretical accumulation of temperature for development from prepupa to adult was 31,550 hour-degrees, while the actual accumulation for the last adult to emerge that season was 33,880 hour-degrees.

In Graph 7 the length of the pupal period has been shown in relation to the time of emergence. The time required for effective temperature accumulations necessary for pupation and emergence becomes progressively shorter, resulting in a "catching-up" effect at the time when the curves fall off most sharply. The peak of emergence occurs at that time when the pupal period has been the shortest. This figure also indicates that for emergence occurring during the first week of July, 1937, the average length of pupation had been approximately one month, checking with previously mentioned field and laboratory observations.

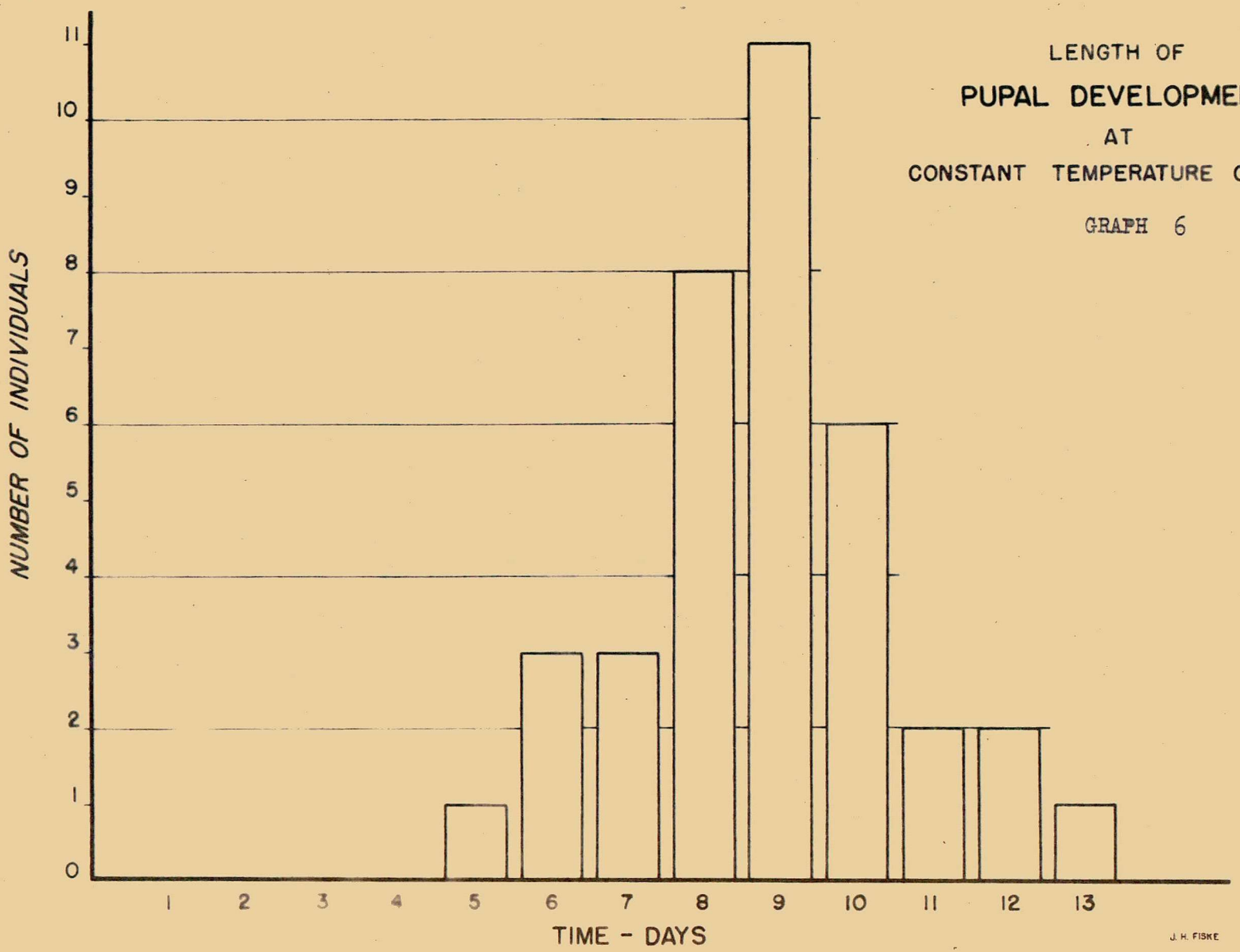

LENGTH OF
PUPAL DEVELOPMENT
AT
CONSTANT TEMPERATURE OF 85°
GRAPH 6
NUMBER OF INDIVIDUALS
0
1
2
3
4
5
6
7
8
9
10
11
1
2
3
4
5
6
7
8
9
10
11
12
13
TIME - DAYS
J. H. FISKE

FIGURE 6

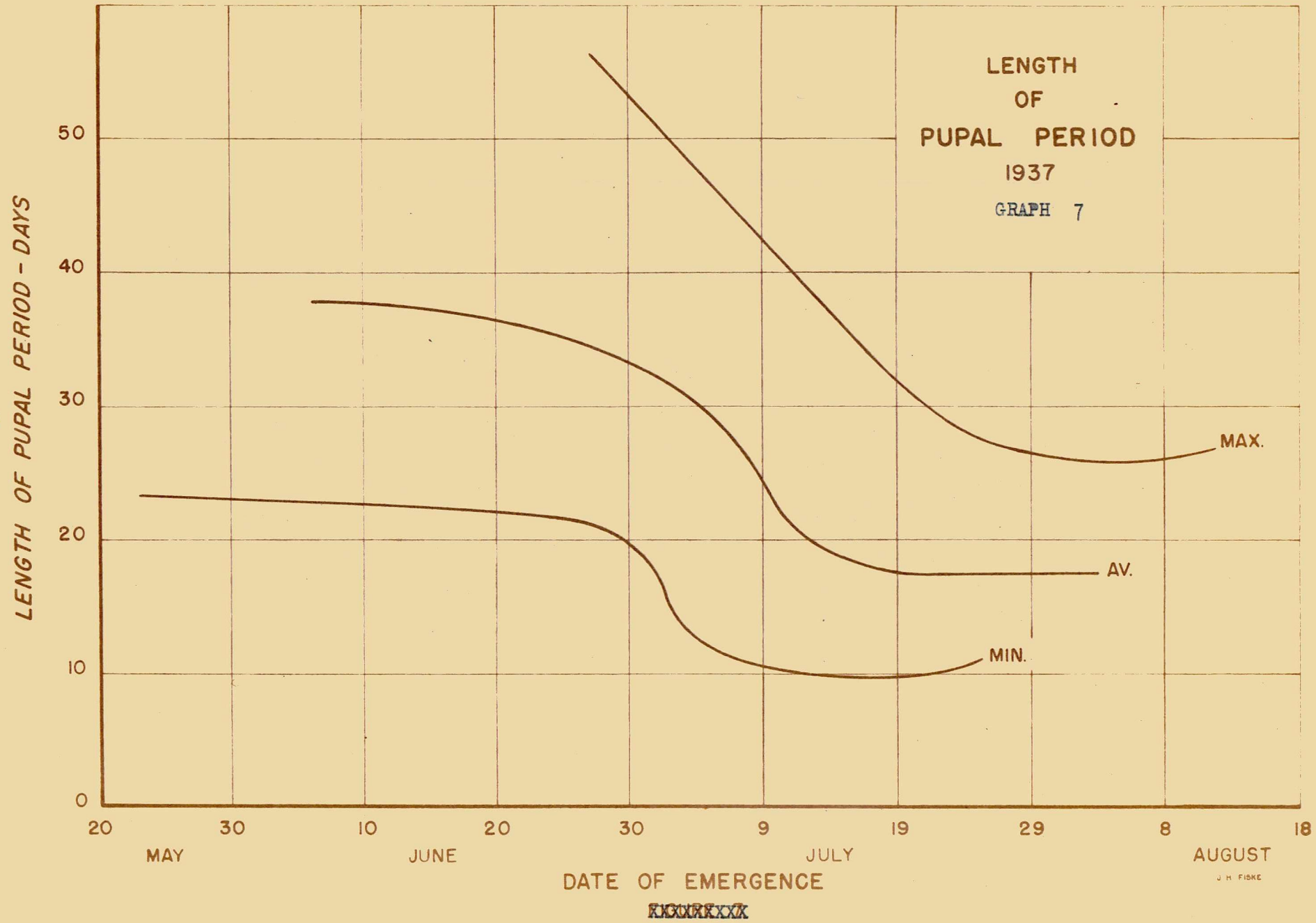

LENGTH
OF
PUPAL PERIOD
1937
GRAPH 7
LENGTH OF PUPAL PERIOD - DAYS
0
10
20
30
40
50
MAX.
AV.
MIN.
20
30
10
20
30
9
19
29
8
18
MAY
JUNE
JULY
AUGUST
DATE OF EMERGENCE
J. H. FISKE

FIGURE 7

SECTION VIII

SUGGESTIONS FOR FURTHER RESEARCH

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COMMENTS ON THE ROLE OF MELANOPHILA CALIFORNICA	73

SECTION VIII

SUGGESTIONS FOR FURTHER RESEARCH

ROOT STUDIES

The examination of root systems of highly susceptible trees (those generally supporting incipient flathead broods) is greatly to be desired. Wagener has stated the situation adequately (Salman, 1939):

> "Little is known of the conditions of root systems of coniferous trees as they relate to top conditions under the ecologic conditions prevailing in this region. More information is needed on both the physical and functional condition of the root systems of trees showing retarded growth or poor crown condition. The effects of drought on the absorbing system as represented by root hairs, rootlets and mycorrhiza needs investigation for the light it may throw on the causes for crown retrenchment and possible relationship with insect attack.
>
> --- W. W. Wagener."

A small amount of root investigation has been undertaken at the Hackamore Laboratory. During the fall of 1938 root washing was tried. The equipment was a Fairbanks-Morse pump with a 1½ horsepower engine, delivering a pressure of 100 pounds at the pump. This equipment was entirely inadequate. The lack of suitable water supply and the type of volcanic soil present over large areas of the Modoc make washing an unsuitable means of studying roots. This season, digging, using CCC labor, has been tried. On two windfalls in the pumice soil the root systems were completely exposed without much difficulty. On two insect killed trees on plot MC-2, the roots of which were partially exposed, the digging was much more difficult. Such work is decidedly unentomological and is hardly justifyable in consideration of results obtained for time spent.

To date the results obtained have been conflicting. The paired windfalls mentioned above, furnished a good example of a high risk and a low risk tree of similar age and size. The high risk tree was heavily infested with unsuccessful incipient galleries, had poor color foliage, short needles, thin crown and dead and dying twigs, while the low risk tree had good color, long needles, dense crown and no dead or dying twigs. Similarly the high risk tree had practically no root system while the low risk tree had a widespread root system with abundant rootlets (Figure 28). The poor condition of roots in the high risk tree was due to some injury to the roots that occurred about 60 years ago.

The tree on which washing was tried in 1938 had what was termed a healthy root system, widespread with many rootlets. There was an occasional dying back of the root in two or three cases. This was also a high risk tree.

The two trees examined on plot MC-2 were both high risk (class 4). As mentioned in Salman's (1939) memorandum, the root systems of both trees were considered healthy. (Figure 29). Several branches were followed to the end and showed an abundance of feeding roots. One of these trees had been attacked by D.b. in the fall of 1938 following three years of successive topkilling by flatheads. The other tree supported an incipient flathead infestation in the top and was attacked by D.b. in the spring of 1939, probably as a result of contagion.

If any progress is to be made in a study of root conditions it will require all the time of one man and a crew of at least six CCC enrollees.

CASE HISTORY STUDIES

Detailed "case histories" to be built up by the study of individual trees is a field of investigation worthy of consideration. This work would include growth studies, root examination and measurements of terminal and twig growth, needle length and needle complement among other factors. Such a"case history" was built up on the pair of windfall trees which has been previously mentioned. Prior to the root injury, some 60 years ago, the high risk tree had been putting on the better diameter growth. After that injury occurred, the low risk tree grew faster, although both trees followed the same trend. The break in this trend, as measured in 10-year periods, occurred in the last decade. The low risk tree showed better growth than in the previous decade, 1919-1928. while the high risk tree showed a distinct drop in growth as compared with the 1919-1928 decade. The heavy, unsuccessful incipient galleries all dated within the past decade. Possibly this lead is worth following to determine if abundance of incipients is associated with slower growth. Twig growth compared over the past 15 years showed that in the low risk trees there had been a general increase in twig growth, while in the high risk tree there had been a slight decrease. Needle lengths were distinctly shorter in the high risk tree, with both trees following the same trend for the past five years. Density of needle complement held to the same relationship.

These results are presented to give an example of the kind of information which it is intended to acquire on a large series of trees. The distribution and abundance of incipient galleries should of course be correlated with other measurements.

Where case history studies are conducted, it would also be desirable to inject the trees prior to felling so as to correlate the factor of conduction with other measurements. Analysis of trees injected with copper sulfate in 1937 has possibly indicated that conduction is somewhat related to loss of growth rings. In two cases there was also some indication that stoppage of conduction was related to the presence of incipient galleries.

GROWTH STUDIES

It is very important that sufficient study be made of the relation of incipients to growth. Particularly it is to be desired that the indication of contunual annual growth being necessary for continued incipient development be investigated. This study is projected for the remainder of the 1939 field season.

CONDUCTION STUDIES.

The possible effect of incipient galleries on conduction is another key factor in placing the role of the California flatheaded borer. The indications heretofore mentioned should be more thoroughly tested. It is also proposed to follow this study during the remainder of the 1939 season.

COMMENTS ON THE ROLE OF MELANOPHILA CALIFORNICA

Although the forest insect problem has been for many years considered a barkbeetle problem, the possible importance of flatheads has been recognized for some time. Hopkins (1899) found what he believed to be the galleries of Melanophila sp. in dead fir, and stated that the species had apparently attacked while the trees were living and healthy. Hopkins predicted that more attention would be paid to flathead borers in the future.

Miller (1911), in a report to the Forest Supervisor at Yreka, in 1911 stated that in four of twenty trees in which flatheads and the western pine beetle occurred together the flatheads apparently had initiated the attack. In two other trees Melanophila sp. alone was apparently responsible for the death of the tree. Miller stated "It is evident that in trees cut, the flathead borer, Melanophila sp., is very closely associated with the western pine beetle".

Person (1930) recorded a decided decline in the relative importance of D. brevicomis on Modoc infestations from 1928 through 1930. Melanophila and Ips emarginatus infestations were the most abundant associated species.

Salman (1935) thought that flatheads had been increasing in importance in recent years. Since that time greater importance has been attached to flathead infestations because it has been shown that where flatheads occur in mixture with other species the former has initiated the attack. The initial dying of many trees may be associated purely with flathead infestations, but with D.b. or other species filling in so that the place of flatheads is obscured.

Concerning the rise and fall of incipient populations in the green stand we have little information. It is apparent, however, that successive attacks by flatheads, with mixed age incipient broods resulting, are common in high risk trees. If the susceptibility logging studies now being carried on at the Black's Mountain Experimental Forest show that loss can be reduced by removing highly susceptible trees, it is perhaps but an academic question as to what factor is the cause of the high risk conditions. It is felt though that more study of the role of M. californica may bring out whether the problem is a silvicultural one, with the cause of high risk timber being entirely climatic factors, for example, or whether it is an entomological problem with the California flatheaded borer one of the factors of primary importance.

It is the opinion of the Berkeley Station that studies on the role of the species should be continued, insofar as it may seem practicable, to more clearly determine if we are dealing with a problem in which the entomological factors may be the key ones.

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PLATE I

Life History Stages of Melanophila californica

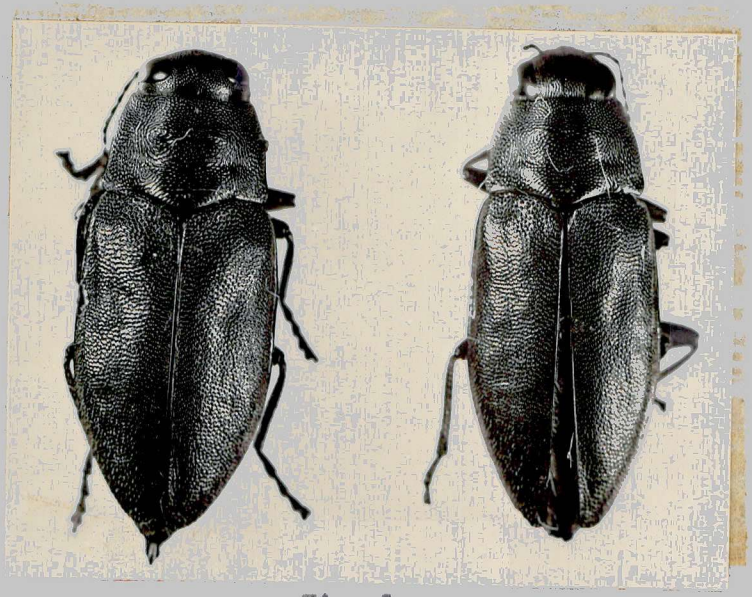

Fig. 1
Adults

Fig. 2
Eggs under surface of bark scale.

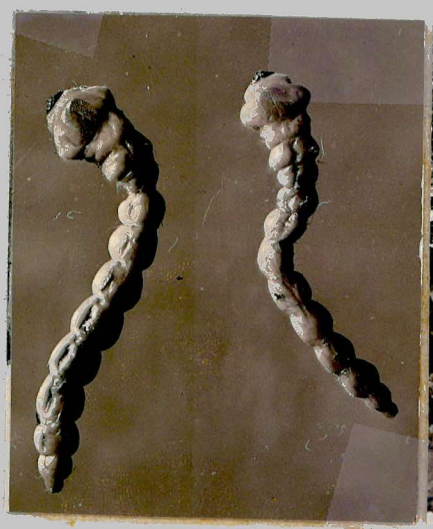

Fig. 3
Incipient stage larva showing mine and scar on outer wood ring.

Fig. 4
Fast growing larvae. (nearly full grown)

Fig. 5
Prepupal larvae in bark cell.

Because of differences in habits, appearance and development, larval stages of M. californica have been divided into incipient, fast growing and prepupal stages. This gives the species six discernable phases of development from egg to adult. All stages shown here are considerably enlarged.

Plate II
COMPARISON OF INCIPIENT AND FAST GROWING
STAGES OF MELANOPHILA CALIFORNICA

Fig. 6

The Incipient Stage

The upper half of this photo shows a larval mine on the surface of the sapwood; the lower half is the inner surface of the inner bark or phloem covering this mine.

The larva shown in this picture began feeding in the cambium in the summer of 1938 (mine starts at right). During this season the tree laid down wood over the mine as shown by the ridge-like growth which slowly increased in size with the larva. When tree was cut in August, 1939, the larva was uncovered in its immediate feeding area which had not grown over. Note the depression in the strip of phloem which was peeled away from the mine.

Fig. 7

The Fast Growing Stage

Inner bark of dead tree showing fast growing larvae and characteristic galleries. As soon as the tree dies, the larvae leave the cambium area and feed on phloem and inner bark, making frass packed mines entirely different from those made by incipient larvae. There is no recognizable difference between the larval mines of Melanophila californica and Melanophila gentilis during the fast growing stage.

Plate III

COMPARISON OF LARVAL MINES OF
M. CALIFORNICA AND M. GENTILIS

Fig. 8. M. californica

Pointer on right indicates beginning of incipient mine; the pointer on left indicates where the larva has changed from the incipient to the fast growing stage, and has entered the phloem area. This change occurs suddenly and the character of the mine is altered.

Fig. 9. M. gentilis

The young larva starts feeding in the phloem area and does not scar the wood. The mine increased gradually in size and there is no distinction between incipient and fast growing stages.

LIFE CYCLE OF A TYPICAL MELANOPHILA CALIFORNICA

MIXED AGED BROOD

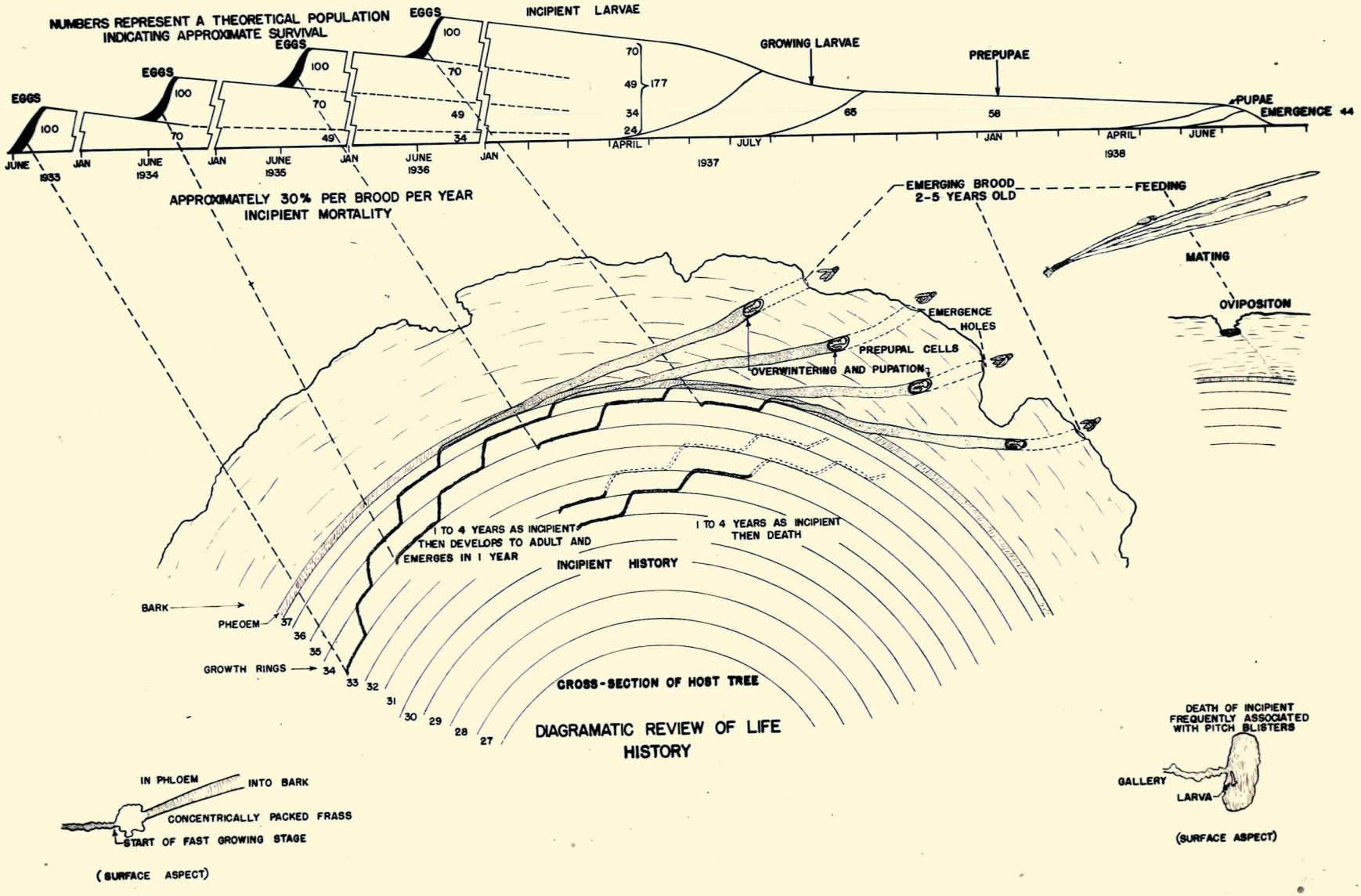

Plate IV
Figure 10

Plate V

SPECIAL HABITS OF M. CALIFORNICA

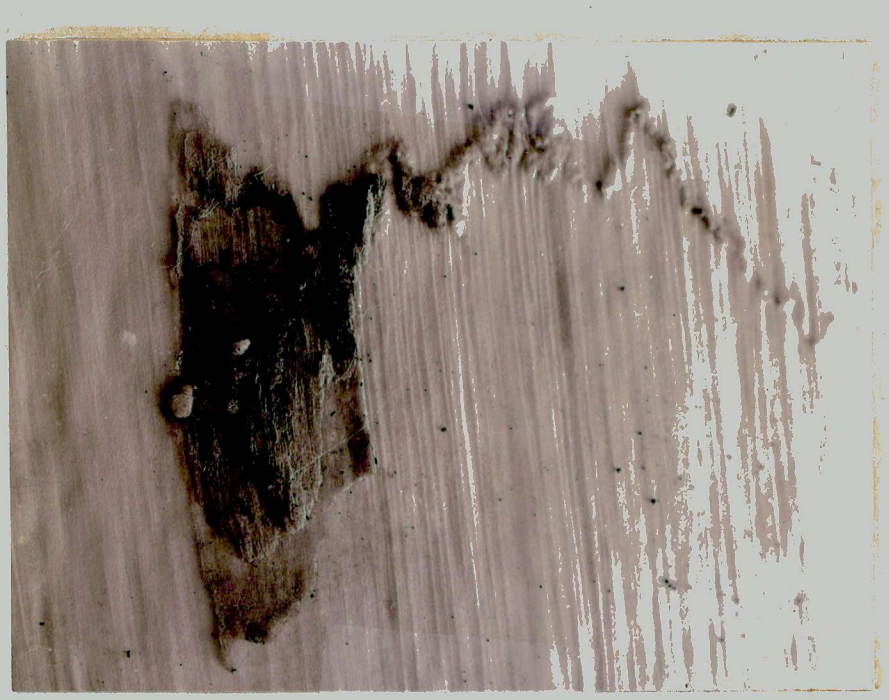

Fig. 11. Pitch Blisters

At times the tree may respond to rapid feeding of incipient larvae and produce pitch blisters between bark and wood. This photo shows one of these blisters in process of formation with larva imbedded in the resin. The larva dies soon after the blister forms. If tree continues growth, these blisters become imbedded in the wood and cause degrade of lumber.

Fig. 12. Prepupal Larval Cell in Sapwood

Where bark is very thin the prepupal larva turns back to the wood and excavates its pupal cell here instead of in the outer bark.

Plate VI

FEEDING HABIT OF M. CALIFORNICA ADULTS

Fig. 13

Injury to Ponderosa Pine Foliage

Feeding of the adults on pine foliage is necessary to sexual maturity and oviposition. The notching of needles shown above frequently causes them to die and fall. Where feeding is concentrated, noticeable defoliation results (see Plate VII).

Adults of M. californica were forced to attack this tree for two successive seasons. Normally, on this site at Hackamore, this insect attacks chiefly slow growing, mature trees. This experiment was planned to determine whether the attack can be established in younger more vigorous trees.

Fig. 14

Tree No. 6 as it appeared in spring of 1937 before cage was installed.

Fig. 15

This type of cage was constructed around the tree early in May 1937, and 173 adults reared from infested bark of other trees were liberated in cage. The cage was removed in October. The same operation was repeated in 1938; 685 more adults were introduced during the season.

Fig. 16

The same tree as it appeared in May 1939, after two successive seasons of attack. Note thinning of foliage due to feeding injury.

Plate VIII

FORCED ATTACK EXPERIMENT - 2.

Figure 17

Unsuccessful attacks and incipient mines on surface of sapwood. Tree Cage No. 4 was erected in 1936 over a pole of average health and vigor. A total of 1029 adult beetles was introduced during the seasons of 1936, 1937 and 1938. In 1938, 274 eggs were also placed in the bark. The tree was felled and examined in detail in June 1939. Living larvae and numerous unsuccessful attacks were found (see Table X). The pits shown in the above figure have been definitely established to be result of attacks of larvae which died while they were in the incipient stage.

Plate IX

FORCED ATTACK EXPERIMENT - 3

Fig. 18

A living M. californica larva was removed from the cambium region at point marked by arrow.

Fig. 19

Detail of larval mine shown in Fig. 18. These figures illustrate one of a number of incipient larval mines found on the sapwood of the caged tree No. 4 (Plate VIII). These larvae had been successful in continuing their attack up to June 1939, when the tree was felled for examination.

Plate X

FORCED ATTACK EXPERIMENT - 4.

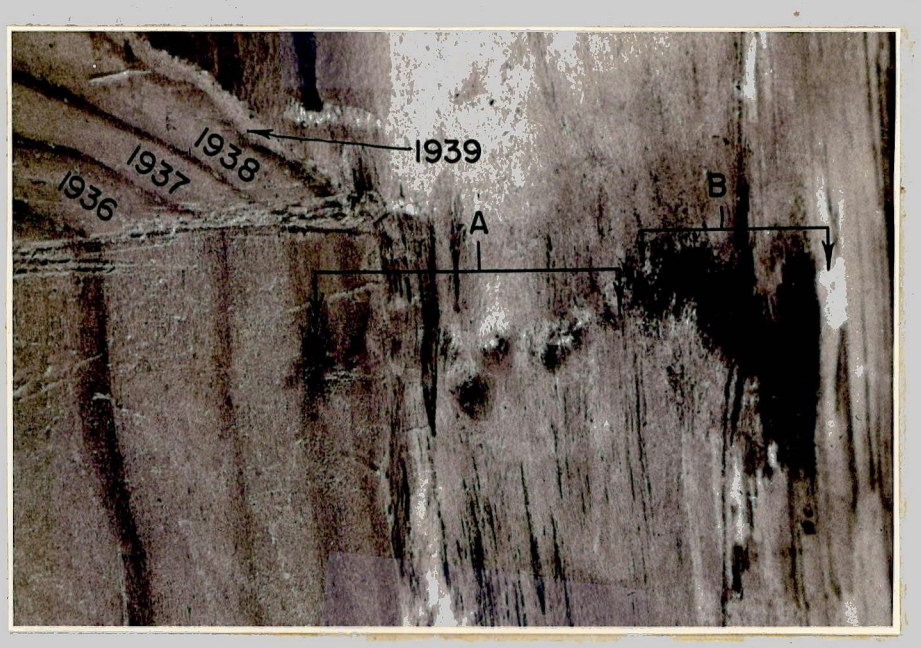

Fig. 20. Relation of Incipient Mine to Annual Growth Rings.

This is the same mine as that shown in Fig. 18, Plate IX. Note in the cross section that the first evidence of a scar due to incipient mine appears in the outer part of the 1937 ring. This represents the first feeding of the incipient larva following the forced attack of that season.

Note that the 1938 ring was laid down while the incipient larva was feeding in the cambium and that ridge caused by the healing scar extends through to the surface of the partial 1939 ring. Bracket A represents length of mine included in this picture which was formed during the 1938 season It is evident that the tree was actively growing during this period.

Bracket B represents the area of the mine formed during the 1939 growing season up until June when the tree was felled. This part of the mine is in the 1939 cambium, but no healing scar had been completely formed before the tree was cut.

Plate XI
MICROSCOPIC SECTIONS OF INCIPIENT MINES
OF M. CALIFORNICA

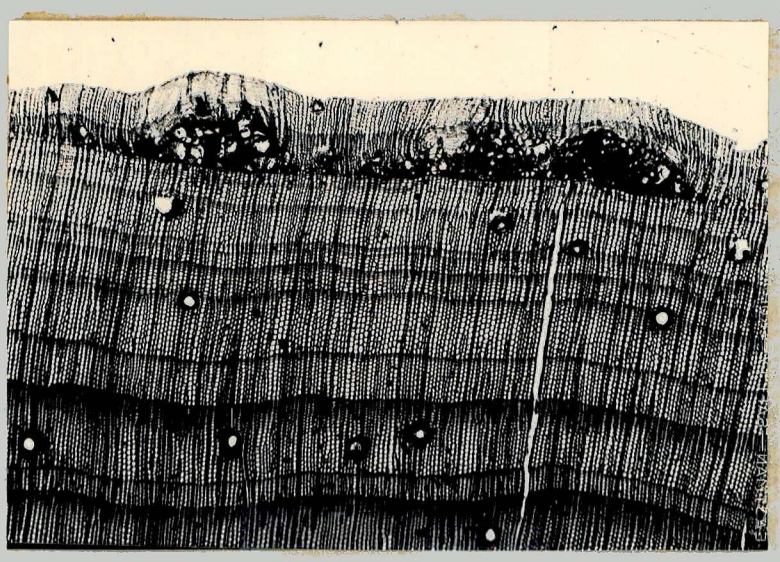

Fig. 21

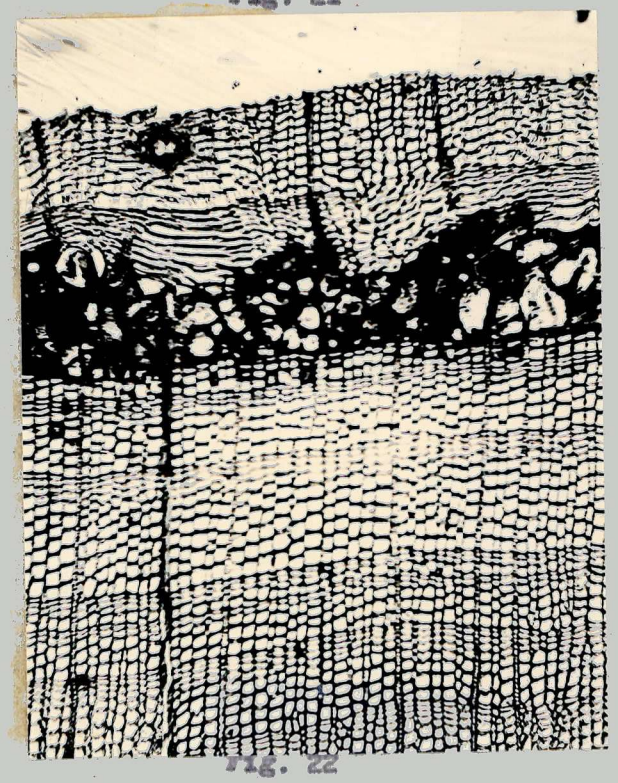

Fig. 22

These sections illustrate the character of the wood tissues which form around incipient mines. Fig. 21 is a cross section showing resinous material imbedded in the mine; also proliferation of parenchymatous tissues where feeding occurred. Fig. 22 is a higher magnification of a similar mine showing abortive character of the cells which form the healing scar. This injury interferes with conduction.

Plate XII
MICROSCOPIC SECTIONS OF INCIPIENT MINES
OF M. CALIFORNICA

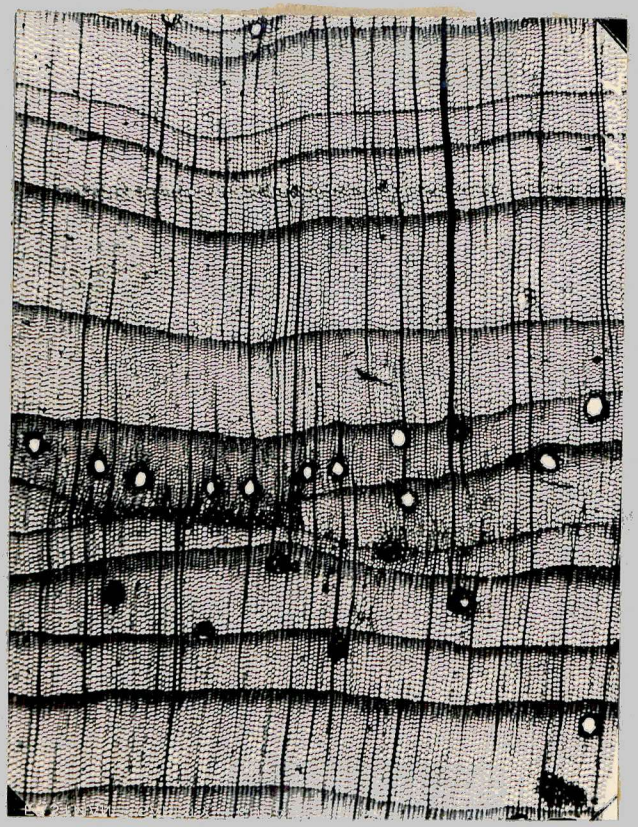

Fig. 23

Resin tubes concentrated around an old incipient mine imbedded in the wood layers. Note resumption of normal growth and cell formation in wood rings laid down in later years.

Fig. 24

Formation of a pitch blister on the surface of the sapwood.

Plate XIII

A HEAVY INFESTATION OF INCIPIENT LARVAL MINES
OF M. CALIFORNICA ON THE SURFACE OF SAPWOOD OF PONDEROSA PINE

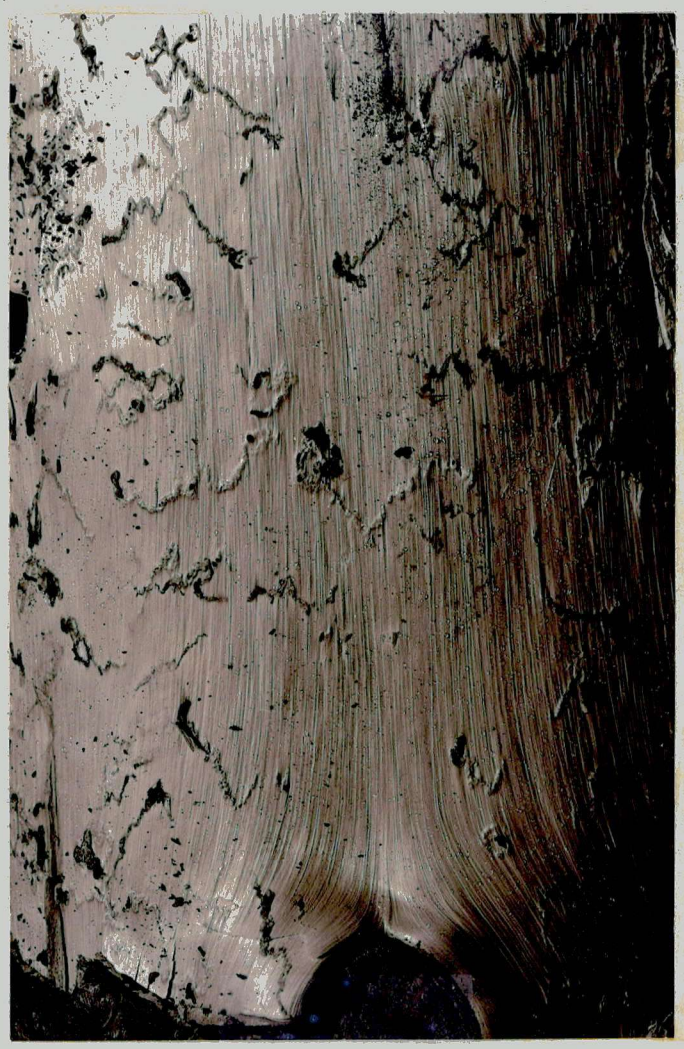

Fig. 25

Heavy infestations are often found in green trees in east side areas. Each gallery represents a lesion of wood tissues which interferes with conduction through the affected area. Such trees become highly susceptible to barkbeetle attack.

Plate XIV
TEMPERATURE STUDIES

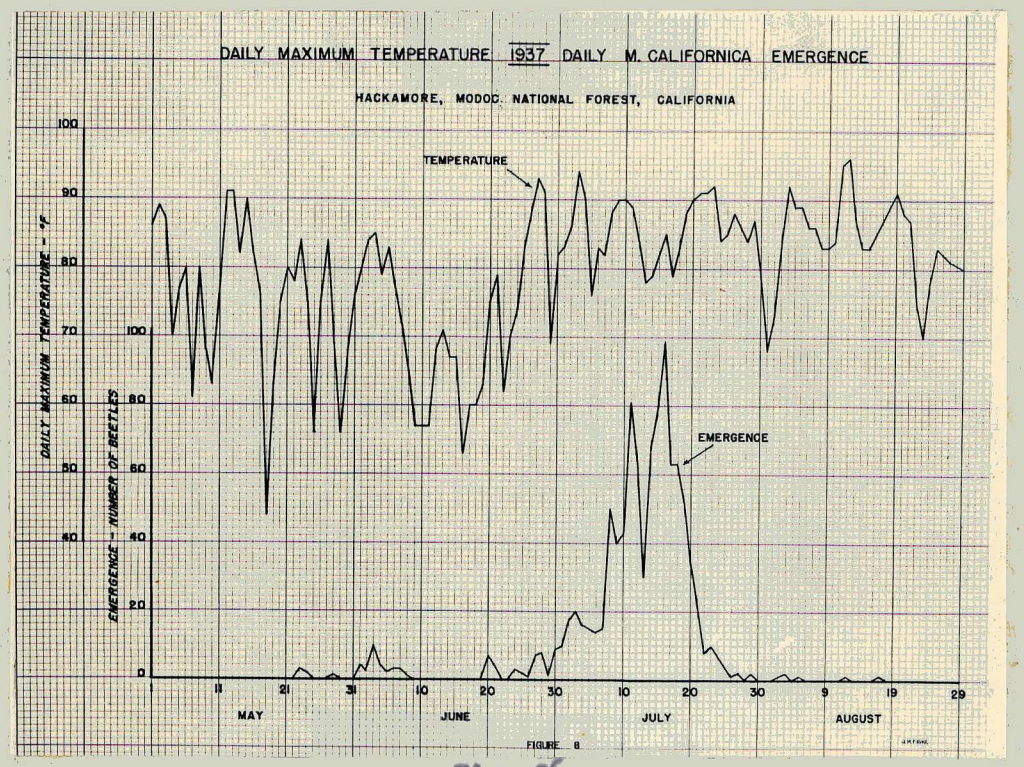

Fig. 26

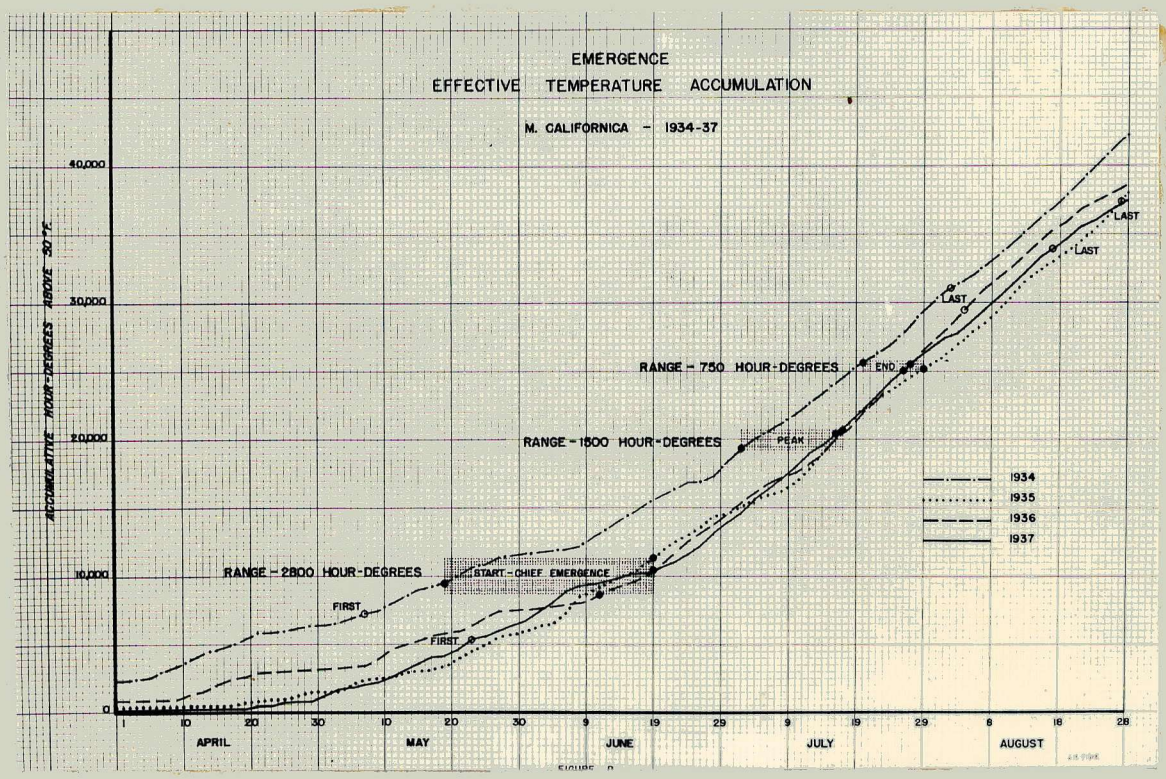

Fig. 27

Studies of the relation of emergence to daily maximum and accumulated developmental temperatures yielded interesting preliminary results.

Plate XV
ROOT STUDIES

Fig. 28

Windthrown Trees, Glass Mountain. Shows poor root system of high risk tree (left) intertwined with good root system of vigorous tree (right). Dead roots and overgrown root stubs were characteristic of the root system of the high risk tree

Fig. 29.

Insect Killed Trees - Plot MC-2. Two insect killed trees, both of which had apparently healthy root systems. Stump in foreground is of tree with successful flathead topkill.

SUPPLEMENTARY NOTES ON

FACILITIES

FACILITIES OF THE HACKAMORE FIELD LABORATORY

For informative purposes a brief description is given of rearing and other facilities at the Hackamore Field Laboratory.

A number of galvanized metal cans were used in bark rearings for securing adults. These cans are provided with a tight cover and are fitted at the lower end with a glass jar. Beetles emerging from the bark make their way to the source of light and are collected from the jar. In addition, a number of common corrugated cardboard cartons fitted with a jar for collecting emergence were used. Containers were set on racks under a tent-fly cover. It was necessary to tanglefoot the supports of the racks to prevent ants from reaching the containers.

For the purpose of observing adult activities as well as attempting forcing attacks on living host material three pole sized trees were completely caged. A 2x4 frame was built around the tree. In 1936 muslin was used for the screening material in part. Since that year 14 or 16 mesh galvanized screening has been used entirely. The screening was removed each fall and the writer has found that it was fully as satisfactory as the higher priced copper screening.

In 1937 a series of six portable cages was built. These were made with 2x2 frames six feet in all dimensions. The sides and tops are bolted together to form a battery of six cages set on a 12 x 18 platform made in two parts. The platform rests on concrete posts which are tanglefooted to keep out ants. These cages have proven very satisfactory in adult, egg and forced attack studies.

During 1936 and 1937 the insectary for log rearings was unsatisfactory. It was built of "bug-lumber" and was not completely insect-proof. Contamination resulted in incomplete records in many cases. In 1938 a new 12 x 14 insectary was built with completely screened sides and was roofed. It has been found satisfactory proof against contamination.

The importance of adequate facilities for biological studies cannot be overemphasized. Suitable facilities at Hackamore have been developed over the period of investigations. It would have been much more desirable to have had these facilities available at the start.